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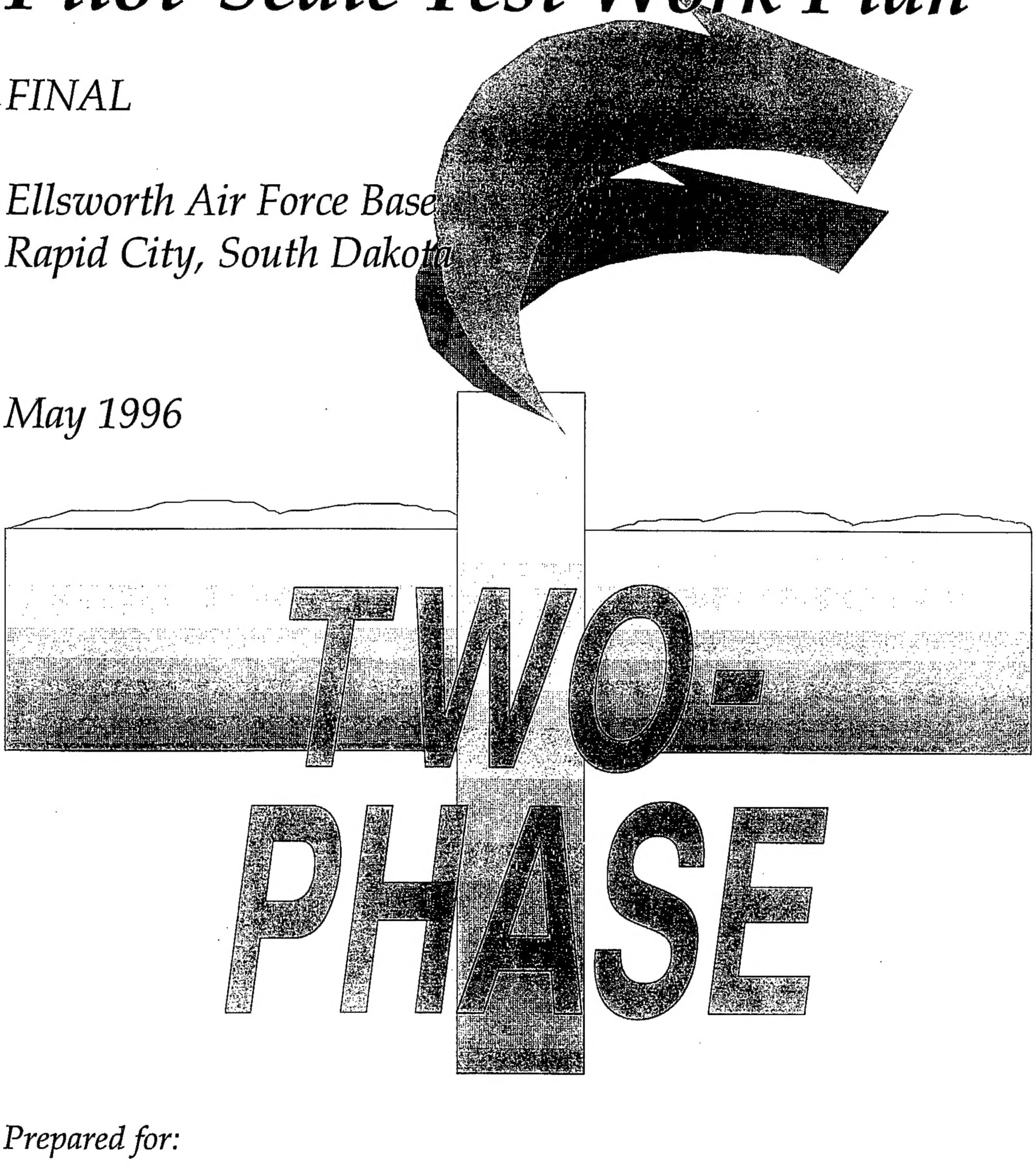
Ellsworth AFB, Operable Unit 11

Vacuum-Enhanced Two-Phase Extraction (TPE) Pilot-Scale Test Work Plan

FINAL

Ellsworth Air Force Base
Rapid City, South Dakota

May 1996



Prepared for:

U.S. Army Corps of Engineers
Omaha District

AQM01-01-0315

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07 May 1996

U.S. Army Corps of Engineers, Omaha District
ATTN: CEMRO-ED-EB (Robert Zaruba)
215 North 17th Street
Omaha, Nebraska 68102-4978

SUBJECT: Contract No. DACA45-93-D-0027, Delivery Order No. 27, Mod No. 4
Final Vacuum-Enhanced Two-Phase Extraction Pilot Scale Test Work Plan,
Operable Unit 11, Ellsworth AFB, South Dakota

Dear Mr. Zaruba:

Enclosed you will find two copies of the final Vacuum-Enhanced Two-Phase Extraction Pilot Scale Test Work Plan for Operable Unit 11, Ellsworth AFB, South Dakota. If you have any questions or comments, please contact me at (916) 857-7281, or call James Machin at (512) 419-5280.

Sincerely,

for FRANCIS E. SLAVICH, PE
Project Manager

c: Margaret Calvert, ACC/ESVW (2)
Dell Peterson, Ellsworth AFB (5)
Peter Ismert, U.S. EPA (1)
Ron Holm, SDDENR (1)
Paul Dappen (1)
Gary Dyke, Radian (1)
James Machin, Radian (2)
Bill BuChans, Radian (1)
Suzanne Sellers, Radian (1)
John Yackiw, Radian (1)
File (2)

RESPONSES TO COMMENTS ON THE DRAFT VACUUM-ENHANCED TWO-PHASE EXTRACTION (TPE) PILOT-SCALE TEST WORK PLAN, ELLSWORTH AFB, SOUTH DAKOTA DATED APRIL 1996

Comment Number	Section	Page/ Paragraph	Reviewer	Comment	Response
COMMENTS FROM THE CORPS OF ENGINEERS, OMAHA DISTRICT					
1	2.0	2-1	Nick Geibel	Has a system similar to this type that is proposed to state some generalities about possible biofouling and incrustation of the well screen and treatment train under similar conditions?	Biofouling and scaling have not been a problem with 2-Phase systems, primarily because of the extreme high velocity of 2-phase flow in the well bore and straw.
2	4.2	4-1, 2nd bullet list, 3rd bullet	Nick Geibel	The piezometers should also be developed to the extent that there will be no doubt that the piezometers are adequately connected to the aquifer and response times in the piezometers	Piezometer development will be added to the final work plan.
3	Figure 4-1		Nick Geibel	With respect to the extraction well and piezometer construction: are continuous wrap or slotted screens going to be utilized for the extraction well and piezometers (I suggest using continuous wrap)? How will the screens be set with respect to the water table during installation (straddling the water table, totally submerged)? What is the slot size opening going to be? With respect to the vapor probes: how far above the screen on the vapor probe will the 10/20 filter pack be? It seems this should be kept to a minimum as to keep the actual zone of monitoring to the length of the screen. What is the slot size on the screen and what type of screen will be used? Is a 12-14 inch diameter borehole really required for a 1-inch diameter vapor probe? Consider a smaller diameter boring for ease of drilling and reduced volume of IDW. It was stated in the text portion of the report that the vapor probes will be set in the clay-sand material, will this be field determined as the actual depth of the vapor probes or will 20 feet always be the case? What is to be done if no clay-sand unit is encountered? I assume drilling logs will be produced for each boring.	Factory-slotted screen was costed and is noted in the work plan, but we will make an effort to get continuous wrap. Ten-foot screen length will be used and will be set into the shale on the bottom; it is expected that this will straddle the water table, but it is not essential. Slot size has been noted as 0.010" on the drawing. The filter pack will be 0.5 ft above the screen on the vapor probes; this will be added to the drawing. The vapor probes will be field slotted. The borehole diameter for a single vapor probe has been changed to 6-8 in. Depth of vapor probes will be field determined and will be set at the full depth of the vadose zone; the clayey sand unit is noted in the text only because that is where the base of the vadose zone appears to be. Drilling logs will be produced.

RESPONSES TO COMMENTS ON THE DRAFT VACUUM-ENHANCED TWO-PHASE EXTRACTION (TPE) PILOT-SCALE TEST WORK PLAN, ELLSWORTH AFB, SOUTH DAKOTA DATED APRIL 1996 (Continued)

Comment Number	Section	Page/ Paragraph	Reviewer	Comment	Response
4	4.3	General	Nick Geibel	Is the test going to be run in a "step" method or in a "constant rate" method? Please give more detail to this in the report.	Each test will be run at a constant rate. This will be added to the text.
5	4.3	General	Nick Geibel	More detail on when samples and field measurements are going to be taken would be helpful.	The sampling schedule is shown on Table 5-3 (5-4 in the final). Field measurement schedule is somewhat flexible, but will be noted in the text.
6	7.0	General	Nick Geibel	Describe what is to be done with the PPE generated from the work performed.	PPE disposal will be added to Section 7.0.
1	General		Ted H. Streckfuss	Provide supplemental information within this section relative to the limitations of this technology. Address items such as maximum depth to which the technology is applicable, typical and maximum vacuum normally applied, and the relationship of applied vacuum to soil type. Also address typical blower applications (liquid ring, rotary lobe, etc.) and indicate which is normally required.	Technology limitations will be discussed in the Technology Evaluation Report. A note on maximum tested depth will be added to Section 2.0. Applied vacuum is noted in Section 2.0. Blower type is noted in Section 3.0.
2	4.0	4-6	Ted H. Streckfuss	Prior to returning the storage tank to its origin, as defined in the third bullet on this page, insure that the tank is adequately decontaminated.	A note on tank decontamination will be added.
1	General		Robert Zaruba/ Kellie Kacheck	Field test will be conducted at BG04 NOT Pride Hangar. Make this correction throughout.	Two tests will be conducted at Pride Hangar and BG-04. The appropriate sections of the text have been expanded and new figures and tables have been added to reflect this.

ELLSWORTH AFB OPERABLE UNIT 11
VACUUM-ENHANCED TWO-PHASE EXTRACTION
PILOT-SCALE TEST WORK PLAN

at

Ellsworth Air Force Base
South Dakota

FINAL

Prepared for:

U.S. Army Corps of Engineers
Omaha District
215 North 17th Street
Omaha, Nebraska 68102

Prepared by:

Radian Corporation
10389 Old Placerville Road
Sacramento, CA 95827

REGISTERED PROFESSIONAL ENGINEER
KEVIN M. MURPHY
No. C 054422
Exp. 12/31/99
CIVIL
STATE OF CALIFORNIA

May 1996

TABLE OF CONTENTS

Page

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS

ACC	Air Combat Command
AFB	Air Force Base
CFR	Code of Federal Regulations
DCE	Dichloroethylene
EPA	U.S. Environmental Protection Agency
EZ	Exclusion Zone
GAC	Granular Activated Carbon
HQ	Headquarters
PPE	Personal Protective Equipment
OSHA	Occupational Safety and Health Administration
OU	Operable Unit
PREECA	Presumptive Remedy Engineering Evaluation/Cost Analysis
QAPP	Quality Assurance Project Plan
QA	Quality Assurance
QC	Quality Control
RI	Remedial Investigation
SDDENR	South Dakota Department of Environment and Natural Resources
SSHP	Site Safety and Health Plan
SVOC	Semivolatile Organic Compound
TCE	Trichloroethylene
V	Volt
VOC	Volatile Organic Compound
WWTP	Wastewater Treatment Plant

1.0 INTRODUCTION

This work plan describes a two-week, pilot-scale treatability study to be performed at Ellsworth Air Force Base (AFB), South Dakota, Operable Unit 11 (OU-11). The location of Ellsworth AFB is shown in Figure 1-1.

The purpose of the study is to gather data to support a presumptive remedy for low to moderate permeability water table aquifers contaminated with volatile organic compounds (VOCs). This will be included in the Presumptive Remedy Engineering Evaluation/ Cost Analysis (PREECA) initiative being developed for Headquarters Air Combat Command (HQ ACC). Vacuum-enhanced two-phase extraction is the remedy of choice. This is defined as the simultaneous extraction of groundwater and soil gas from the same well with the application of a vacuum to the well. For this test, one version of this technology, known as the Xerox 2-PHASE™ Extraction (2-PHASE), will be used.

This pilot study will provide site-specific contaminant removal data and subsurface response data to be applied toward the evaluation of vacuum-enhanced two-phase extraction as a presumptive remedy technology. The primary objectives of this short-term, pilot-scale test are to demonstrate the contaminant removal effectiveness of 2-PHASE at removing contaminants at this site, facilitate the engineering evaluation and cost analysis of 2-PHASE, and evaluate the feasibility of 2-PHASE as a presumptive remedy.

This work plan is a supplement to the Quality Assurance Project Plan (QAPP) for the remedial investigation at Ellsworth AFB. This document and all activities associated with this pilot test will be performed in accordance with the QAPP.

OU-11 is the basewide groundwater operable unit for Ellsworth AFB. The data collected from previous investigations in OU-11 have been used to characterize the subsurface features and the nature and relative extent of contamination at the site. Groundwater contamination has been identified in several locations. This pilot study will consist of two 7-day tests that focus on two separate plumes in OU-11. One plume is near Bldg. 7504 (Pride Hangar) within the South Docks Area. The other is in the vicinity of well BG-04 in the northeast part of the Base and extending east of the Base boundary. The primary groundwater contaminant of interest is trichloroethylene (TCE). In addition, total petroleum hydrocarbons (TPH) as purgeable JP-4 (Pride Hangar only) and 1,2-dichloroethylene (DCE) were identified in groundwater beneath these areas. The subsurface deposits have low permeability and consist of clay; clayey silt, sand, and gravel; and weathered and fractured shale (EA, 1995).

In an effort to identify feasible extraction and treatment alternatives for the PREECA project, HQ ACC, the U.S. Army Corps of Engineers (Omaha District), and Ellsworth AFB would like to demonstrate the effectiveness of 2-PHASE extraction for removing contaminants from the subsurface.

The 2-PHASE technology has been shown to be a highly effective technology for extracting volatile organic compounds (VOCs) from low to moderate permeability soils similar to those found at this site. 2-PHASE simultaneously extracts contaminants from groundwater and soil using a high vacuum. As a result of the turbulence and low absolute pressure created by the applied vacuum, VOCs present in extracted groundwater volatilize (strip) and combine with the vapor phase VOCs extracted from the soil. The extracted mixture of air and entrained water enters a separator on the surface where the liquid and vapor phases are separated, treated, and discharged.

The evaluation of the 2-PHASE technology will be based on a review of analytical data and field measurements collected prior to, during, and after the test. Groundwater and soil gas contaminant concentrations will be measured in samples collected from the extraction well prior to and after the test. Liquid and vapor contaminant concentrations will be measured in the liquid and vapor extracted from the subsurface at various times throughout the test. Field measurements include liquid and vapor flow rates, groundwater drawdown, and the

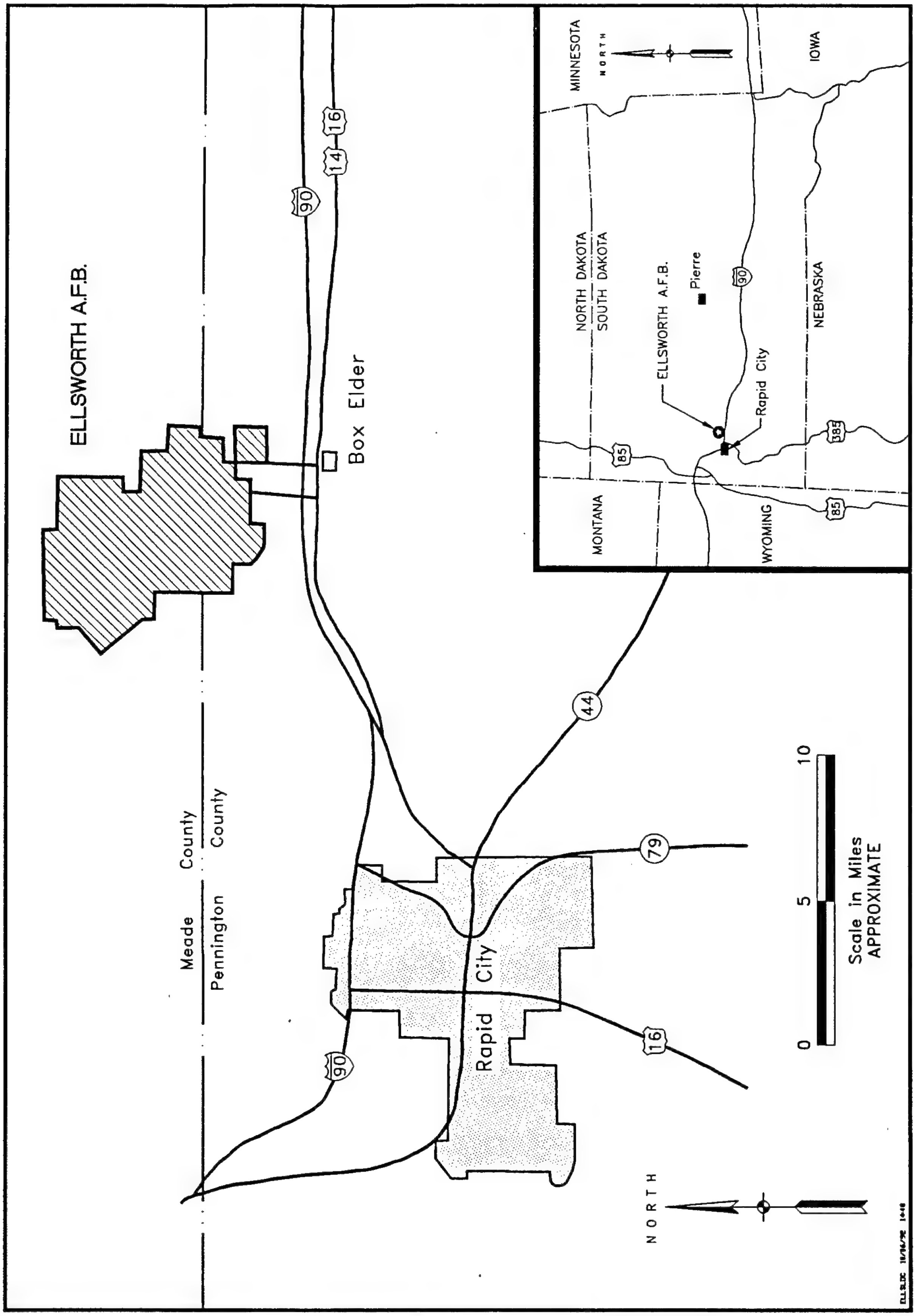


Figure 1-1. Ellsworth AFB Location Map

extent and magnitude of vacuum influence. Operational data for the 2-PHASE equipment will also be recorded for the duration of the test. These data will be used to refine the subsurface conceptual model for 2-PHASE and provide detailed information for the evaluation of this remedial technology as a presumptive remedy.

In addition to fulfilling the objectives above, collected analytical data will also provide information needed to support the selection of a remedial technology for these sites. All data collected during the test is intended to be used to select and design a full-scale extraction and treatment system for the sites.

2.0 TECHNOLOGY DESCRIPTION

The 2-PHASE process was developed for the remediation of VOCs and other contaminants in low to moderate permeability subsurface porous deposits. The process is a modification of conventional vacuum extraction employing a high-vacuum pump and a small-diameter suction pipe (straw) installed into a larger diameter extraction well. The lower end of the straw is set at the desired groundwater drawdown depth, usually within inches of the total well depth, and the wellhead is sealed. High vacuum (approximately 18 to 26 in. of mercury) is applied to the straw, causing vapor in the well to be drawn into the pipe at a high velocity. Liquid (groundwater and contaminants) present in the well bore is aspirated into small droplets by the high velocity flow and becomes entrained in the vapor. The vapor consists of soil vapor drawn in from the surrounding formation and, during startup, air introduced at the wellhead (aspiration air) to enhance liquid entrainment. The technology has been successfully tested at depths exceeding 150 feet, but has been shown to be most effective at depths of less than 50 feet. Figure 2-1 shows a diagram of the 2-PHASE well to be used for the test.

Vapor and entrained liquid from the extraction well are conveyed under vacuum up the straw and through a hose toward the vacuum source. The extreme turbulence in the formation, straw, and hose facilitates transfer of volatile compounds from the liquid phase to the vapor phase. The contaminant transfer process employs many of the same principles used in conventional air strippers. The applied vacuum, or low absolute pressure in the system, enhances contaminant transfer by increasing the volatilization of contaminants. The hose is connected to a separation vessel installed immediately upstream of the vacuum pump. The vessel separates the entrained liquid from the vapor so that each phase can be treated and discharged separately.

2-PHASE removes liquid, vapor, and adsorbed contaminants from soil at a high rate and subjects a large soil volume to treatment, which can substantially reduce the overall time needed for site remediation. The vacuum applied to the extraction well increases liquid flow to the well, lowers the water table, and evacuates liquid from the area around the well. As the water table is lowered, more of the soil formation is exposed to vacuum, causing vapor flow to the well to increase. Vapor, having a much lower effective viscosity than water, is pulled through the formation at a high rate. The vapor flow volatilizes adsorbed and free-phase contaminants and removes them in the vapor phase.

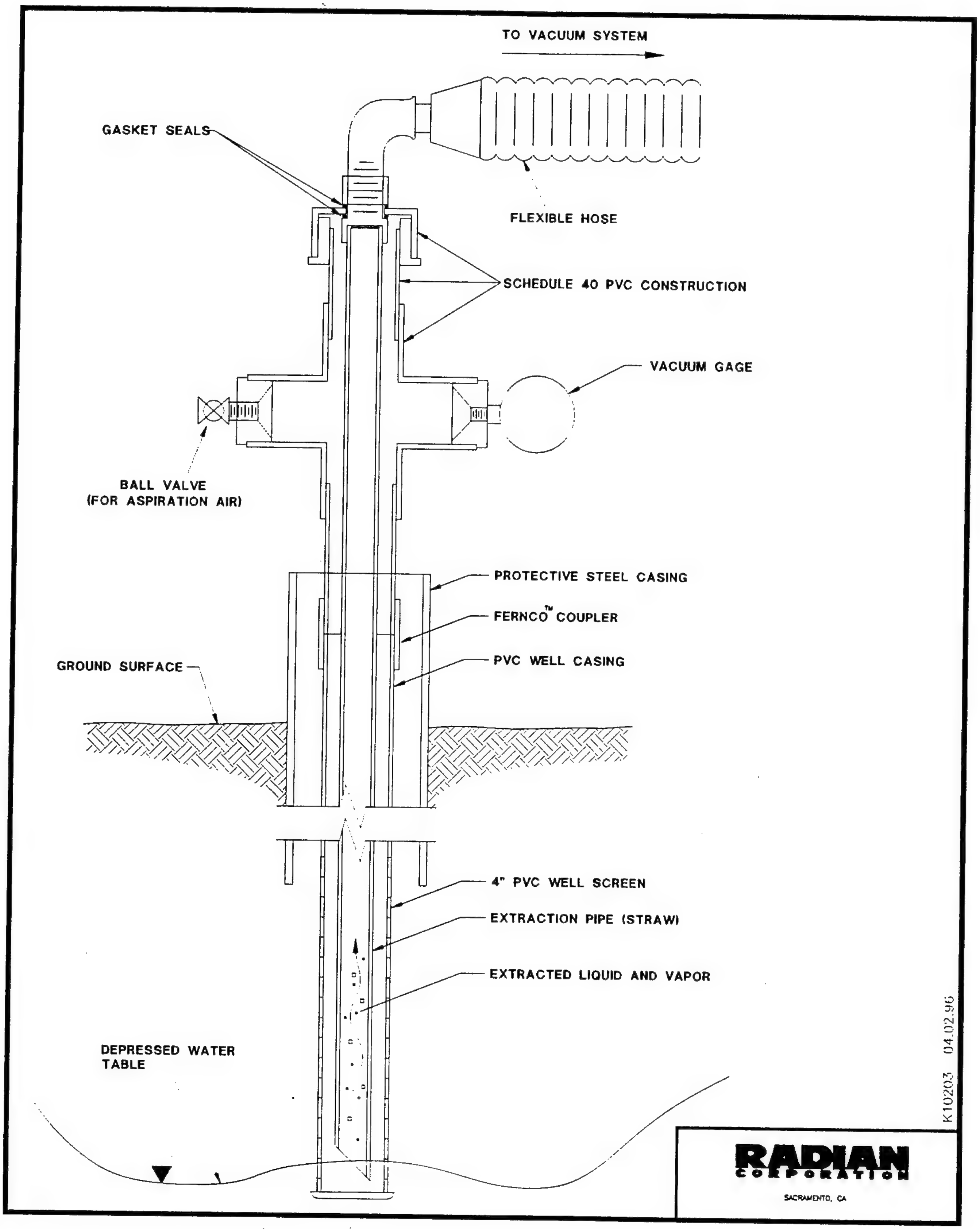


Figure 2-1. 2-PHASE Wellhead Assembly and Extraction Well

3.0 PILOT TEST APPARATUS AND SITE DESCRIPTION

3.1 Pilot Test Apparatus

A schematic of the equipment to be used for the pilot test is presented in Figure 3-1. It includes the extraction well, wellhead assembly, mobile 2-PHASE vacuum system, liquid phase activated carbon treatment, and liquid storage tank.

The wellhead assembly will be fabricated in the field similar to that shown in Figure 2-1. A 2-inch-diameter vacuum-rated flexible hose will be attached to the wellhead to convey extracted contaminants to the vacuum system.

A mobile 2-PHASE vacuum system owned by Radian Corporation will be delivered to Ellsworth AFB for use during the technology demonstration. The trailer-mounted system includes a liquid/vapor separator, liquid ring vacuum pump, extracted liquid transfer pump, seal fluid separator and reservoir, vapor aftercooler, liquid flow totalizer, and vapor flow rotometer. The system is semiautomated and includes level sensors for all fluid vessels, temperature and vacuum gages, and a fail safe control system. It is powered by a single 240-V, three-phase electrical connection. A diesel- or gasoline-powered generator will be rented locally and transported to the site to power the system.

A liquid phase activated carbon drum will be purchased for the treatment of extracted liquid. After the test, the carbon will be characterized and disposed. Since the carbon will contain solvents, it will be managed as hazardous waste and will be manifested by the Base. This will be coordinated with the Base Hazardous Waste Coordinator, Mr. Rich Parkinson.

The State of South Dakota Department of Environment and Natural Resources (SDDENR) will not require vapor treatment for the short duration of the pilot test. The extracted vapor will be discharged directly to the atmosphere. A copy of the final report with calculations of the total mass of VOCs emitted will be submitted to SDDENR following the test.

A rented portable tank will be used to store treated groundwater. The water will be sampled and analyzed with expedited turnaround to ensure adequate treatment prior to discharging. Ricer Company, a local hauling contractor, will be used to transport the treated water to the Base wastewater treatment plant (WWTP) for disposal as needed during the test and upon test completion.

3.2 Pride Hangar Plume

The area around monitoring well MW941103 located in the South Docks Area of OU-11 near the southeast corner of Bldg. 7504 (Pride Hangar) will be used for one of the tests (Figure 3-2). This area has been characterized by the OU-11 Remedial Investigation (RI) conducted by EA Engineering, Science, and Technology (EA); site data collected during the RI was used in preparation of the work plan (EA, 1995). An analysis of groundwater from MW941103 is presented in Table 3-1. The only organic contaminants detected were VOCs; metals were in a range consistent with acceptable background concentrations. Very little contamination was detected in the soil boring at this location. Logs for existing wells in the area are provided in Appendix A.

The primary contaminant of interest is TCE. A TCE plume map of the entire South Docks Area is presented in Figure 3-3. Groundwater flow in the area is to the south-southeast. The lithology of the site is clayey silt and sand underlain by weathered and fractured shale (Pierre Shale) at approximately 30 feet. Depth to the water table is about 22 feet.

This site is appropriate for the demonstration for the following reasons:

- The total depth of the wells in this area (20-30 feet) is within the proven effective range for 2-PHASE.

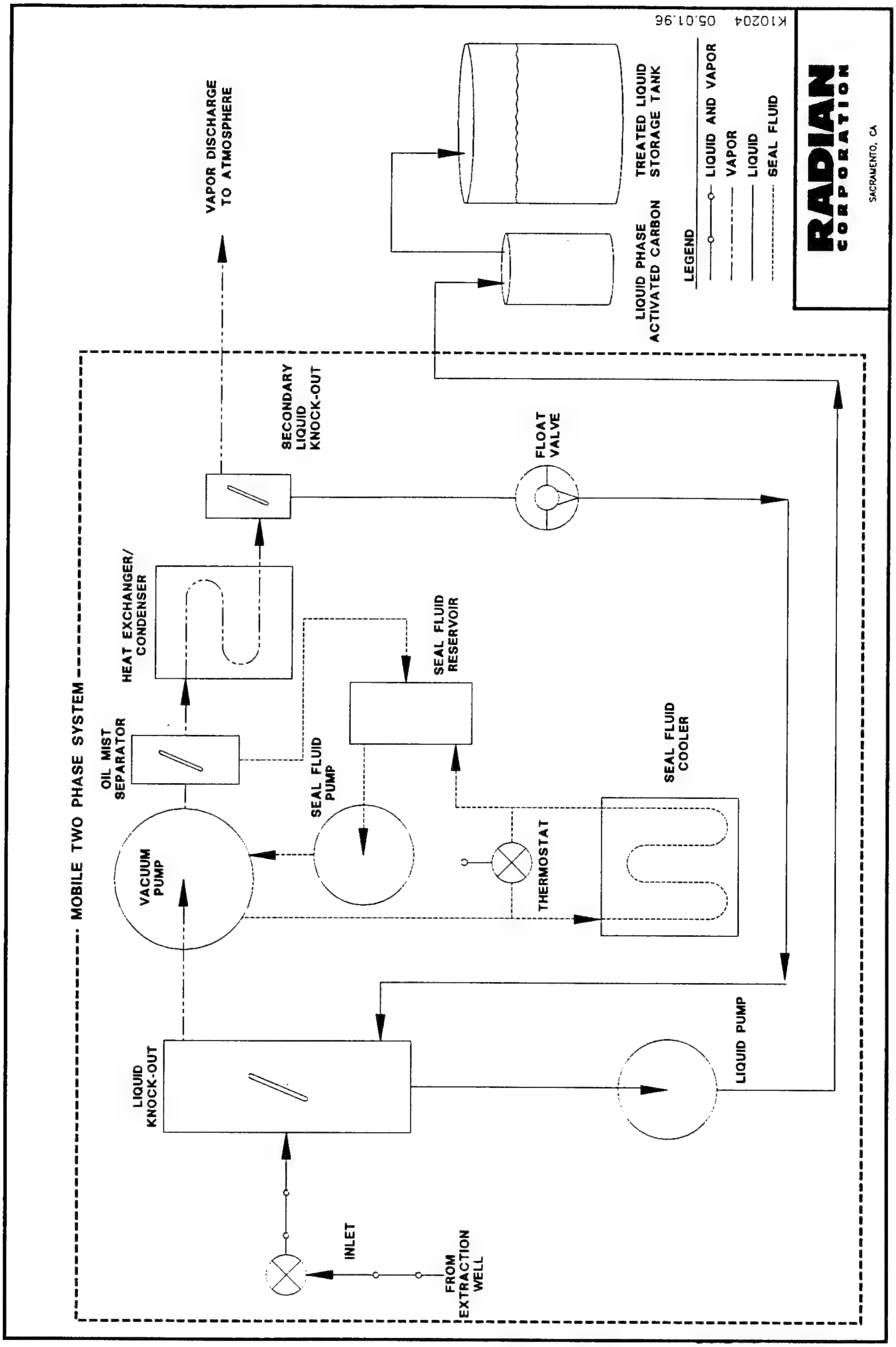


Figure 3-1. 2-PHASE Extraction Apparatus Schematic

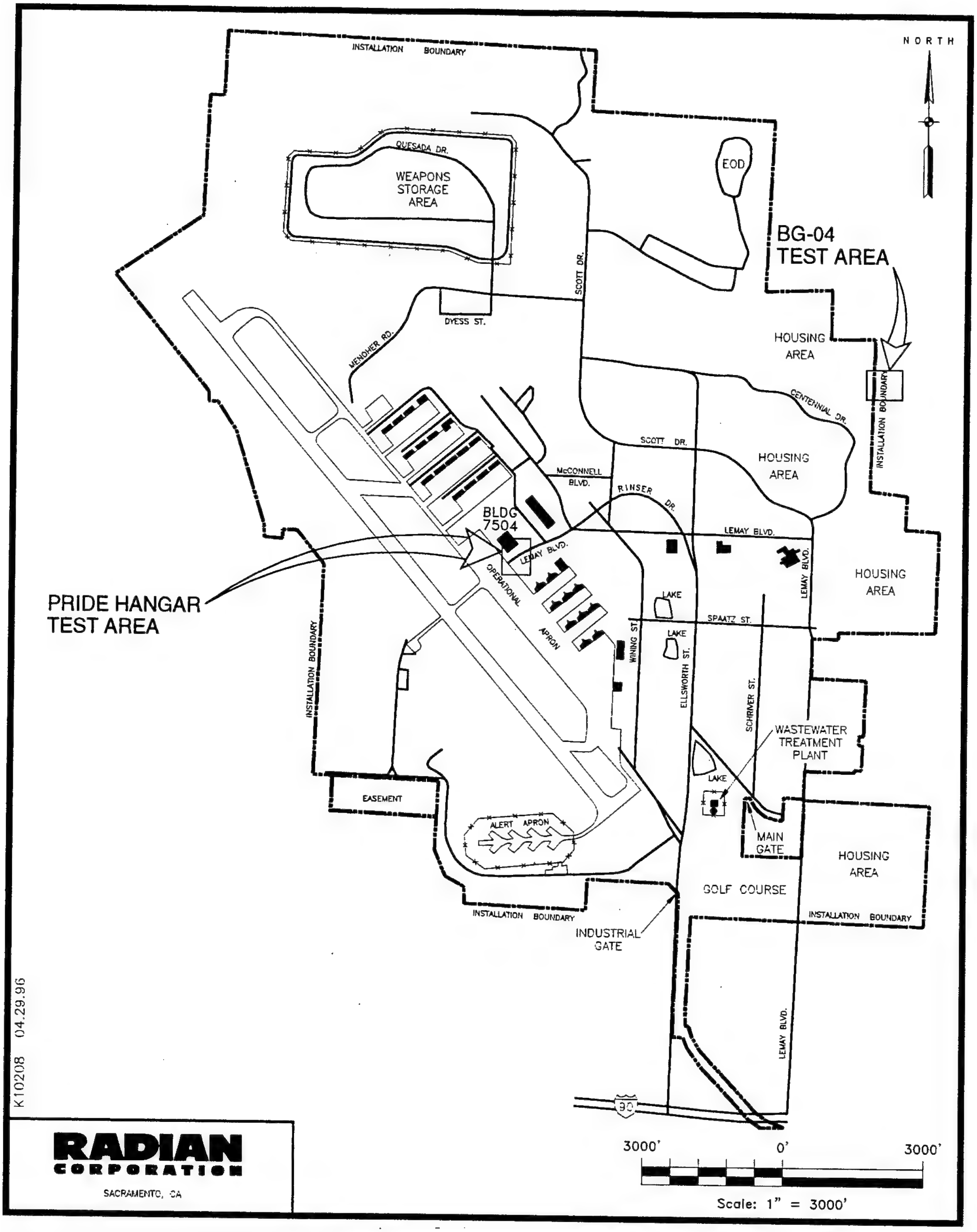


Figure 3-2. Test Location

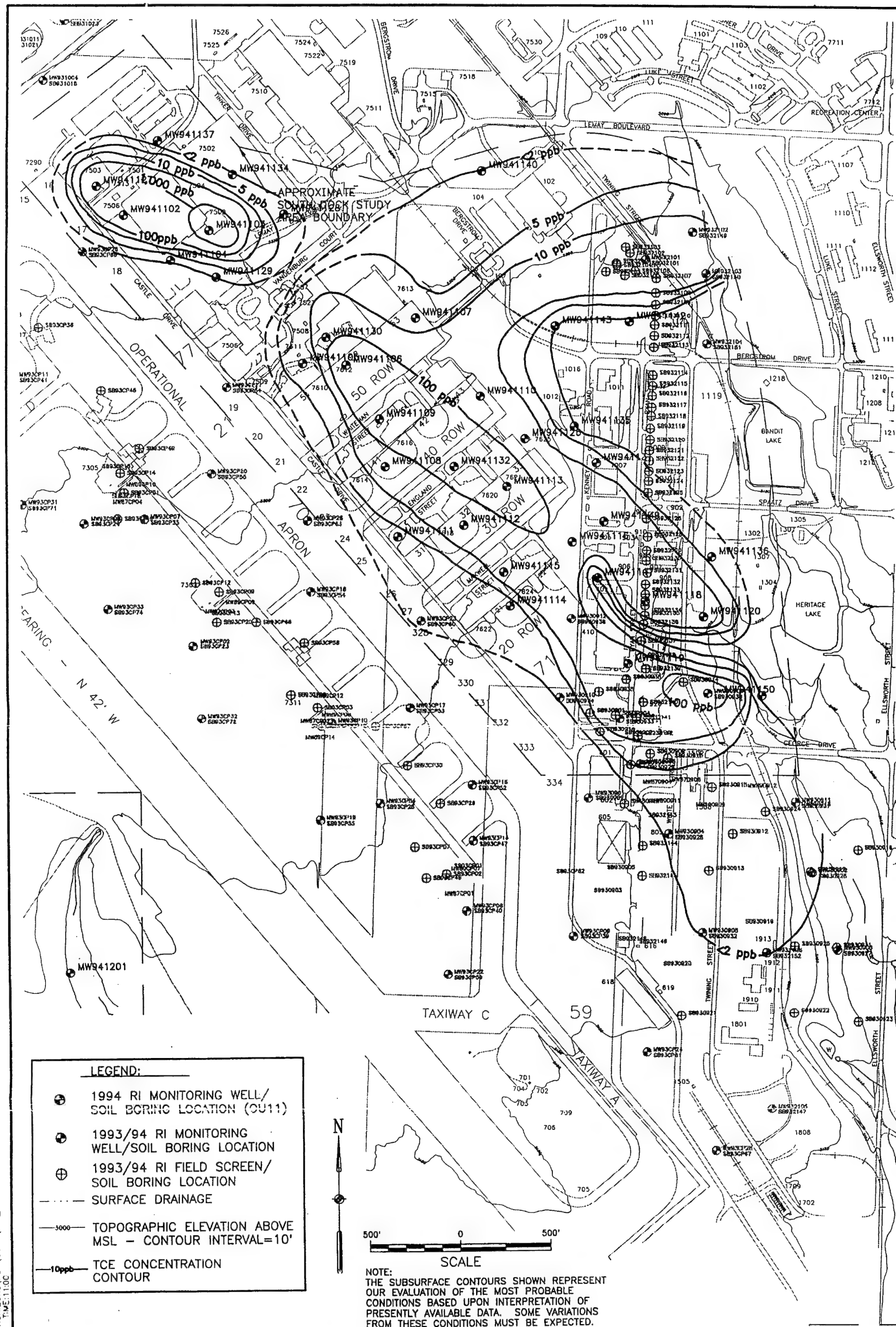
Table 3-1. Groundwater Sampling Results,

Parameter	Concentration, µg/L	
	MW941103 Pride Hangar Plume (15 Aug. 1994)	MW941148 BG-O4 Plume (19 Jan. 1995)
Volatile Organic Compounds		
1,2-Dichloroethylene	35, 10 (dup. samples; field screening) <100 (laboratory)	10 [1]
Chloroform	200 B	ND
Methylene chloride	40 BJ	ND
Trichloroethylene	7000	23, 20 [1]
JP-4, purgeable	2500	ND
Semivolatile Organic Compounds, Polynuclear Aromatic Hydrocarbons, Pesticides		
None detected	--	--
Metals, Dissolved		
Aluminum	150 J	69.9 J
Barium	16.0 J	13.6 J
Calcium	135,000	49,800
Magnesium	54,800	32,900
Manganese	5.2 J	ND
Potassium	9380	7,170
Sodium	178,000	187,000
Antimony	5.2 J	5.3 J
Arsenic	2.0 J	ND
Selenium	21.2	17.3

Note: Only parameters above detection limit shown.

[1] 15 June 1995 sampling
B = detected in blank
J = detected below contract required quantitation or detection limit
ND = Not detected

Source: EA, 1995



ELLSWORTH AIR FORCE BASE	ELLSWORTH AFB RAPID CITY, SOUTH DAKOTA	OU-11 RI SOUTH DOCKS AREA ISOPLETH MAP - TCE CONCENTRATIONS (ug/l) MONITORING WELLS	DESIGNED BY	DRAWN BY STAFF	DATE SEP 95	PROJECT NO. 60378.90
			CHECKED BY TMO	PROJECT MGR.	SCALE AS SHOWN	FIGURE 4-16

DRAWING NAME: F:\HORIZONS\NEW\OU11\TCE_MW DATE:06/14/1995 TIME:11:0C

Figure 3-3. Pride Hangar TCE Plume Map, South Docks Area (Source: EA, 1995)

- The existing MW941103 can be used as one of the piezometers during the test. Other nearby wells (MW941104 and MW941129) can also be used for monitoring. A new 4-inch-diameter extraction well will be installed.

- This area is located in a potential off-site source area of TCE contamination. It is between the base boundary and the highest single off-site TCE hit. Implementing 2-PHASE extraction in this area may help remediate this source and/or pull it back toward the base boundary.

- The site is contaminated with a combination of VOCs (primarily TCE up to 7,000 µg/L) and purgeable JP-4 up to 2,500 µg/L), which are present mostly in the saturated zone.

- The formation has a relatively low hydraulic conductivity. No slug tests were performed as part of the OU-11 RI, but tests were performed on 12 wells in the OU-9 RI. OU-9 is approximately 3500 feet southeast of the Pride Hangar. Slug tests in OU-9 indicate hydraulic conductivity in a range of 1.7×10^{-4} to 3.5×10^{-5} cm/sec.

- During development of MW941103, a flow of about 0.5 gpm was obtained. This indicates a low productivity formation.

3.3 BG-04 Plume

The area east of monitoring well MW941148 in the off-base portion of the BG-04 plume will be used for the other test (Figure 3-2). Rust Environment and Infrastructure (Rust) performed a direct push investigation for VOCs and a seismic survey in this off-base plume in 1995. No borings were completed. The nearest boring is at MW941148 on the base boundary. This well was installed by EA in 1994 as part of the OU-11 RI. The data from the investigation was used in preparation of this work plan (Rust, 1995 and 1996; EA, 1995).

Analysis of groundwater from MW941148 is presented in Table 3-1. The only organic contaminants detected were VOCs; metals were in a range consistent with acceptable background concentrations. TCE was the major contaminant (23 µg/L). A TCE plume map for the BG-04 area is presented in Figure 3-4. Note that this map was prepared prior to the Rust direct push off-base survey and that the plume is now known to extend further off base. No contamination was detected in the soil boring from MW941148. The well log is presented in Appendix A.

The direct push investigation yielded 31 groundwater samples along and east of the base boundary. Most samples were analyzed by a mobile laboratory. The results revealed TCE in excess of 5 µg/L at 13 locations. The highest TCE concentration was 1068 µg/L immediately north of water well ELN200 and about 600 ft east-northeast of MW941148. Other high concentrations (up to 227 µg/L) were detected north of MW941148 along the eastern base boundary. A copy of the technical memorandum documenting this study and the comments from EPA are presented in Appendix C.

The lithology of the area is clay and clayey/silty sand and gravel underlain by weathered and fractured Pierre Shale. Based on the off-base seismic survey, depth to the Pierre Shale ranges from 5 to 28 ft. A copy of the seismic survey is presented in Appendix D.

Groundwater flow in this area is presumed to be toward the southeast. The seismic survey revealed paleochannels in the surface of the Pierre Shale, and it is likely that groundwater and the bulk of the TCE contamination follow these channels. The major channels cross the base boundary north of MW941148 where some of the higher TCE concentrations were found. No aquifer testing has been performed in this area. Depth to the water table has not been determined off base, but it ranges from 11 to 29 ft in the on-base BG-04 area.

Because of the lack of site-specific data, it is uncertain at this time whether this site is

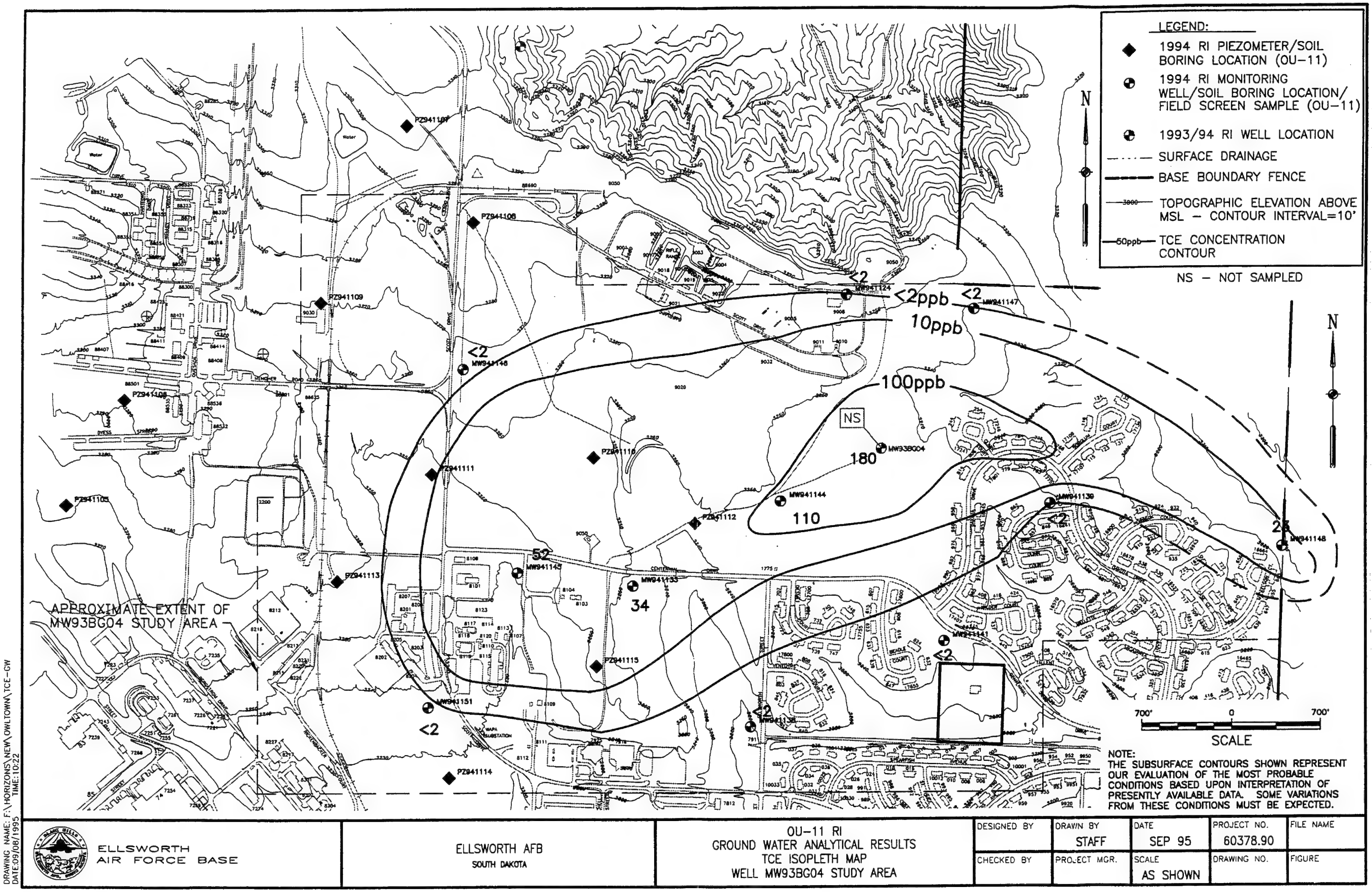


Figure 3-4. TCE Plume Map, BG-04 Area (Source: EA, 1995)

appropriate for the 2-PHASE technology. The test will help determine that. It is suspected that it is an appropriate site, and it has been selected for the following reasons:

- The site is contaminated with elevated levels of VOCs (primarily TCE) which are present in the saturated zone.

- The site likely has a moderate hydraulic conductivity (k). Similar sites elsewhere on the Base have shown k values in the range of 10^{-3} to 10^{-5} cm/sec.

- Depth to the Pierre Shale in this area is within the proven effective range for 2-PHASE.

- The plume has migrated off base and is the object of a time-critical removal action. Prompt action on this plume is a priority for the Base. If the technology is effective, the test results could help the Base design and execute the removal action.

4.0 TESTING PROCEDURES

The pilot-scale test of 2-PHASE will consist of two one-week tests to be conducted in OU-11 on new extraction wells near MW941103 and off base near MW941148. The test start date is scheduled for 11 May 1996. All activities (equipment monitoring, sample collection, sample control, and sample analysis) will be conducted in accordance with the procedures and protocols described in the U.S. Environmental Protection Agency (EPA)-approved Ellsworth AFB QAPP, the Site Safety and Health Plan (SSHP) included in Section 8.0, and the OU-11 SSHP.

4.1 Well/Piezometer Installation

4.1.1 Pride Hangar

An extraction well (EW-1) will be installed downgradient (south-southeast) of well MW941103. An array of three piezometers and three vapor probes will be installed around the extraction well to assess the performance of the 2-PHASE system. MW941103 will be used as one of the piezometers. Maxim Technologies or another drilling subcontractor will install the wells and vapor probes through the use of a hollow-stem auger drilling rig in accordance with the Ellsworth AFB QAPP. A well and vapor probe construction detail is shown in Figure 4-1. Liquid piezometers will penetrate the saturated zone to the underlying shale. Vapor probes will extend to approximately two feet above the saturated zone and will be screened in the overlying (clayey sand) interval.

Figure 4-2a shows a site plan and Figure 4-2b shows a projected cross section of the extraction well, the piezometers, and the vapor probes. The exact locations and depths will be determined in the field. The piezometers will be used to monitor groundwater drawdown during the test. Groundwater levels will be measured using a battery-powered water level meter. The vapor probes will be used to monitor the extent and magnitude of vacuum influence on the unsaturated soil formation. The groundwater piezometers will also be used to measure vacuum in the saturated zone as it becomes unsaturated during the test. Applied vacuum will be measured using a Magnehelic® pressure gauge.

4.1.2 BG-04 Area

An extraction well (EW-2) will be installed off base northeast of well MW941148 and northwest of well WWELN200. The well will be located in the area of a suspected paleochannel in the Pierre Shale (inferred from the seismic investigation [Appendix D]) and in an area of suspected elevated TCE concentrations (from the direct push investigation [Appendix C]). This area is located upgradient of the highest off-site TCE hit from the direct push investigation (near WWELN200) and downgradient of the highest TCE hits along the eastern base boundary and is considered a potential source area. Thus, the 2-PHASE extraction will be focused on the potential source, with the goal that it may help draw the source back toward the base boundary.

An array of three piezometers will be installed around the extraction well to assess the performance of the 2-PHASE system. Drilling will be similar to that described for the Pride Hangar area. Piezometers will be screened across the water table to allow for measurement of induced soil vacuum and groundwater levels in the same well. Wells will penetrate the saturated zone to the underlying shale. A piezometer and extraction well construction detail is shown in Figure 4-3.

Figure 4-4a shows a site plan and Figure 4-4b shows a projected cross section of the extraction well and piezometers. The exact locations and depths will be determined in the field. There is very little subsurface data available in this area, so screened intervals and lengths could change. Measurements during the test will be similar to that described for the Pride Hangar area.

Because of the lack of data for the off-site area, field activities will involve real-time screening and decision-making for determining well depths, screen lengths, and screened zones. During drilling, core samples will be screened

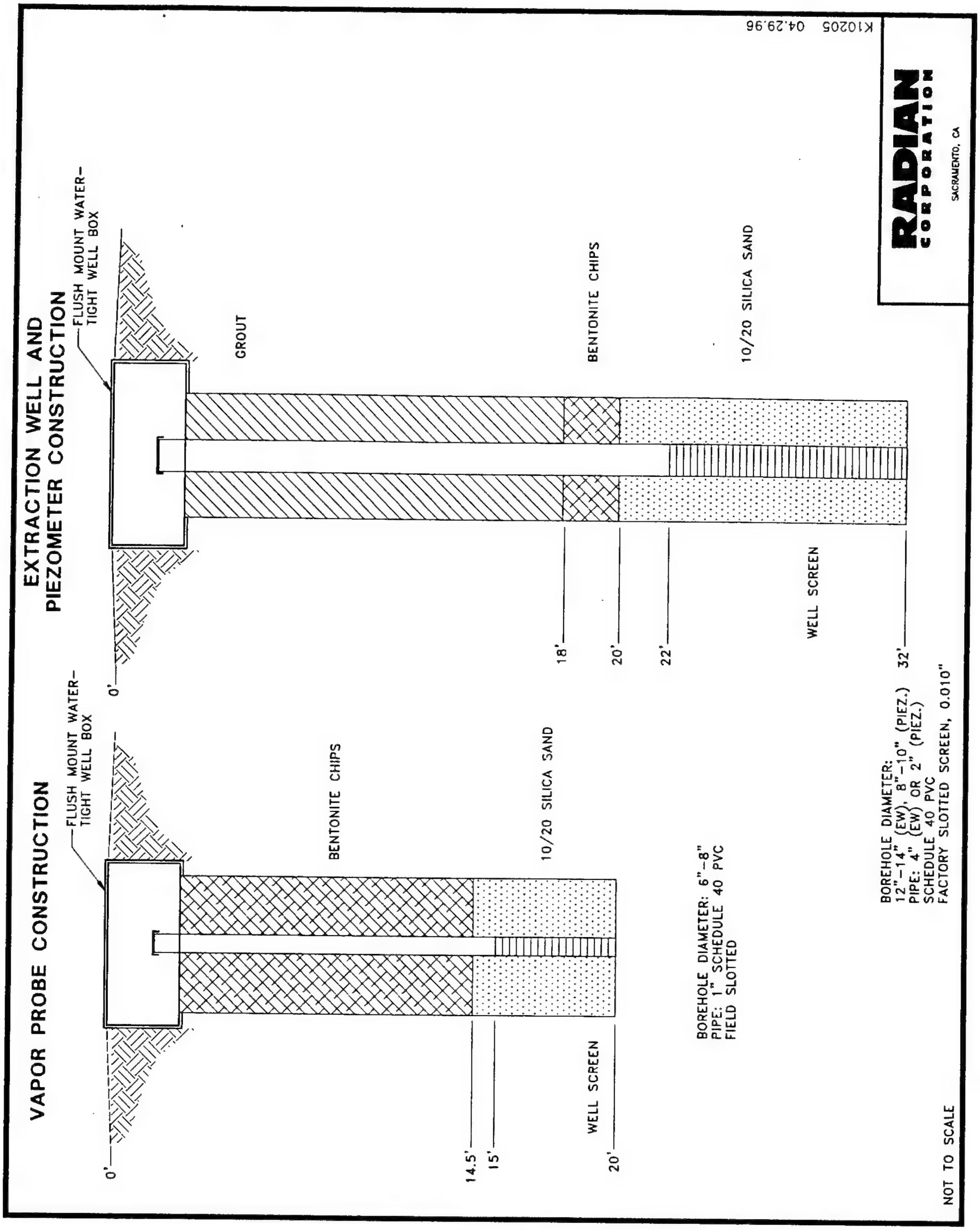


Figure 4-1. Extraction Well, Vapor Probe, and Groundwater Piezometer Construction Detail (Pride Hangar)

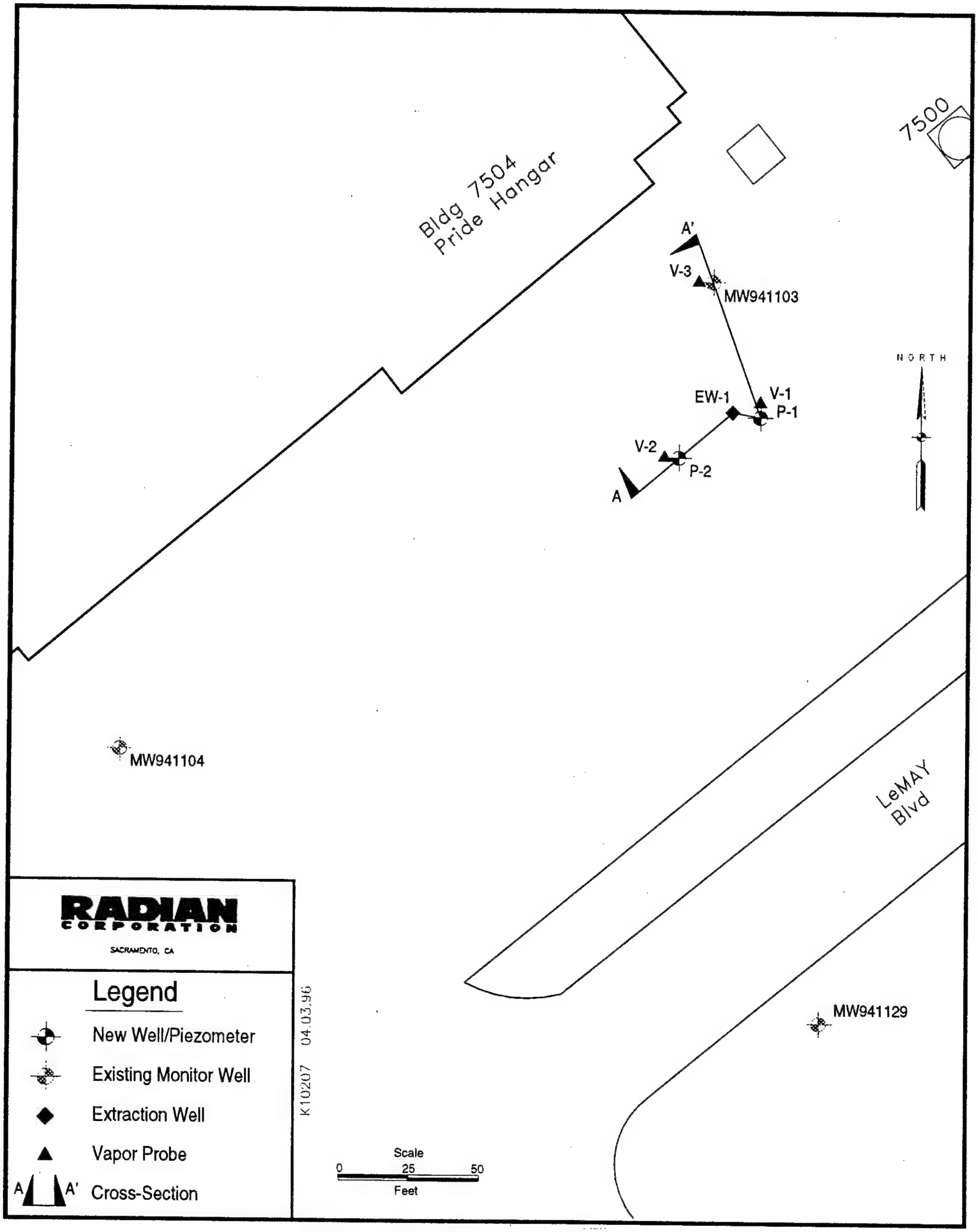


Figure 4-2a. Pride Hangar Site Plan

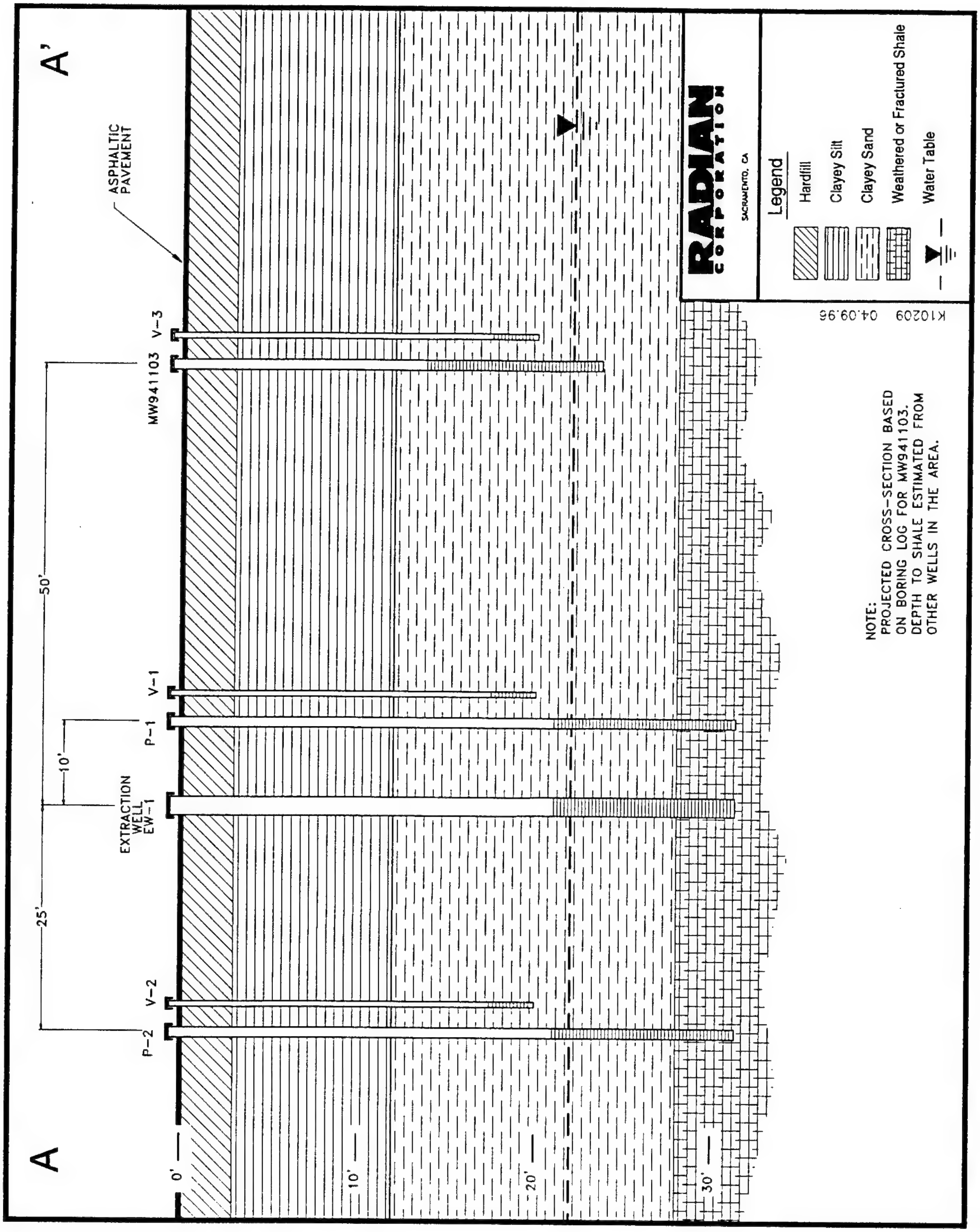


Figure 4-2b. Pride Hangar Site Cross Section

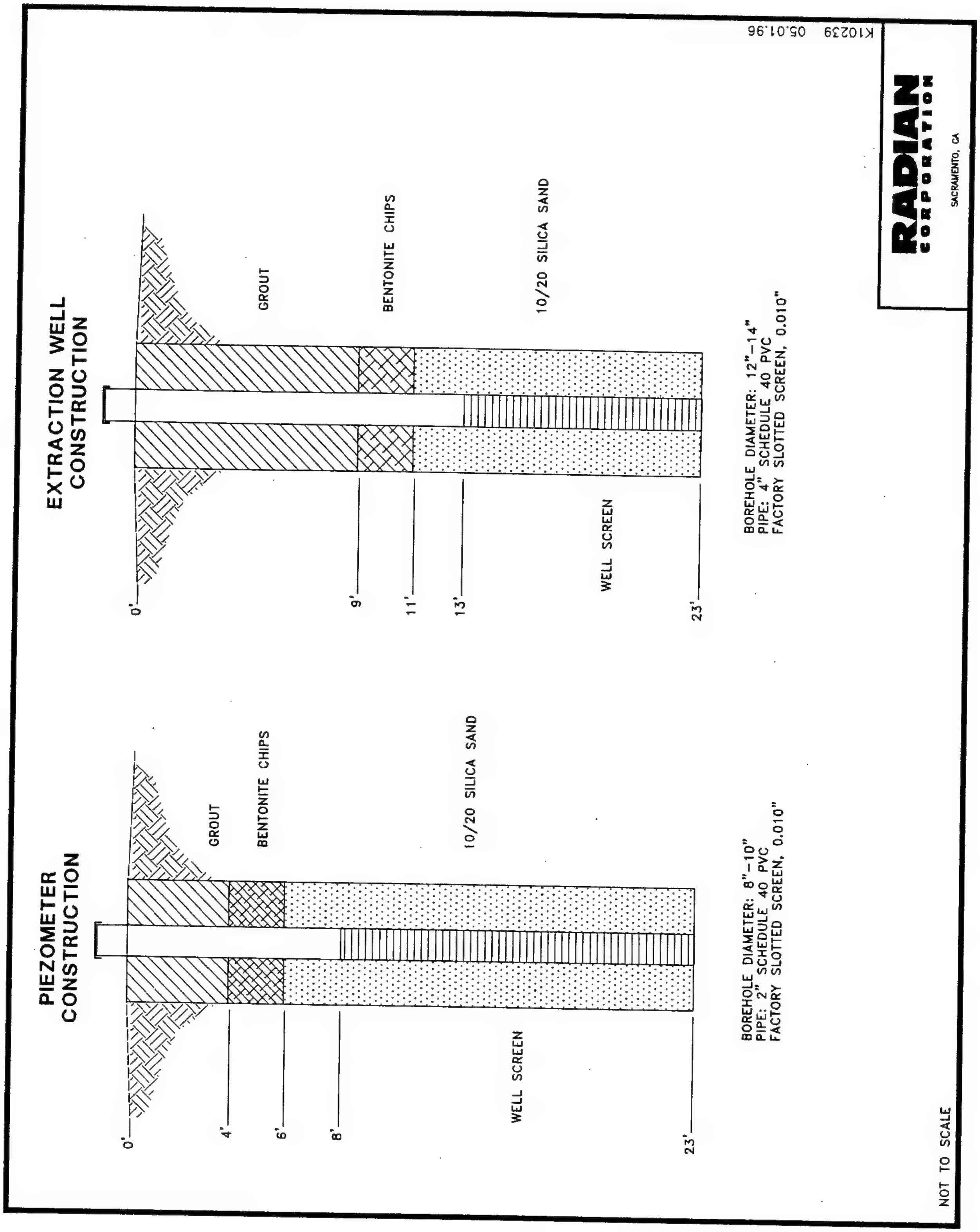


Figure 4-3. Extraction Well and Piezometer Construction Detail (BG-04)

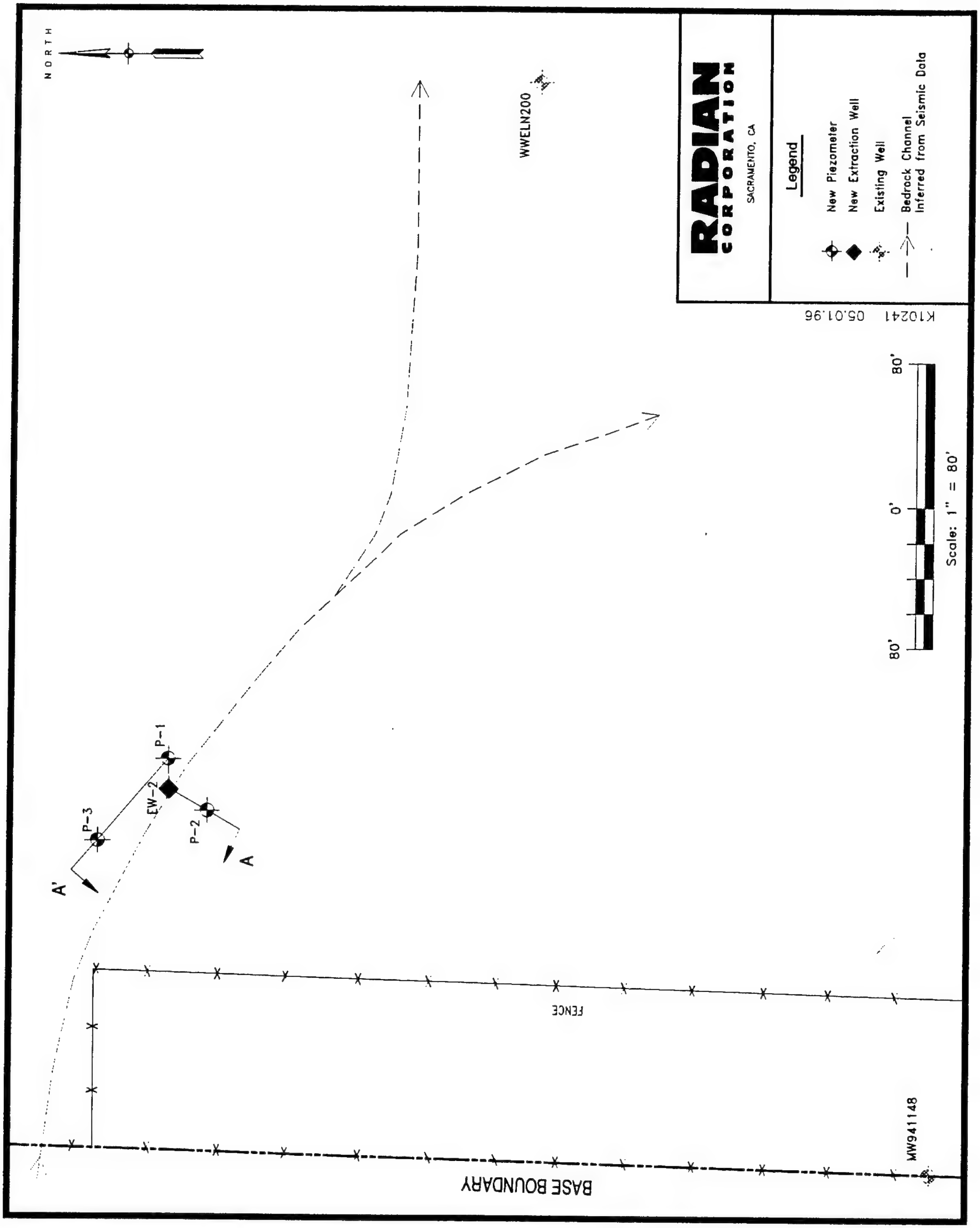


Figure 4-4a. BG-04 Site Plan

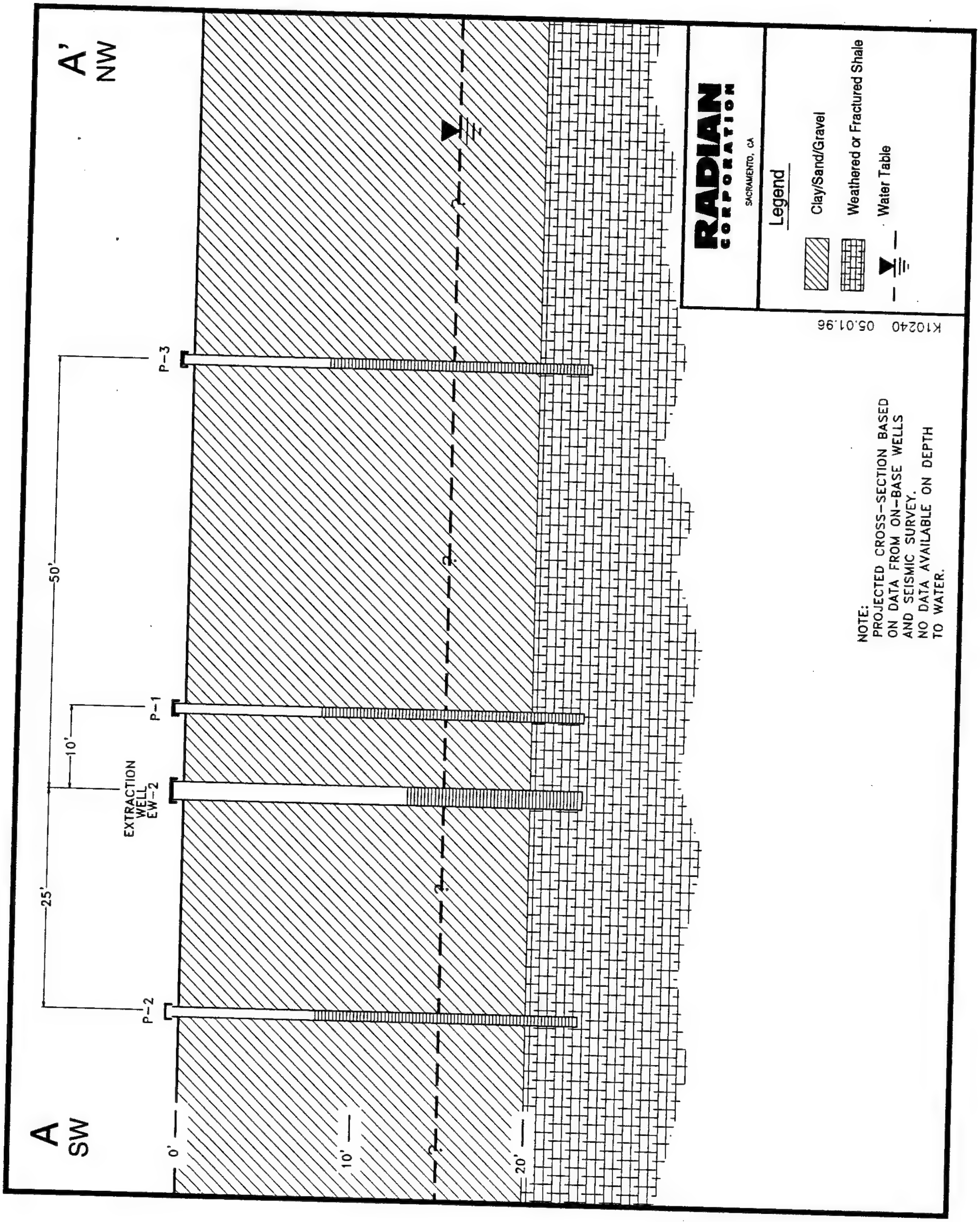


Figure 4-4b. BG-04 Site Cross Section

for VOCs with a photoionization detector (PID). It is anticipated that the wells will fully penetrate the saturated zone into the weathered and fractured shale. However, if screening data show that the highest concentrations are shallower, the well depth and screened interval will be selected to target that zone. However, if elevated concentrations are entirely within the shale, the screen will be set into the shale to maximize the effect in that zone and minimize short circuiting from the more permeable overlying sediments.

4.2 Equipment Mobilization and Test Setup

The following equipment and materials will be mobilized to the OU-11 site in preparation for the pilot test. All equipment and materials will be available on site the week prior to the test.

- The 2-PHASE system will be transported to the site and placed near the extraction well.
- A portable 240-V, 3-phase generator and supplementary fuel tank will be rented locally to power the 2-PHASE system.
- A liquid phase activated carbon drum will be purchased and delivered to the site via common carrier.
- A portable storage tank will be rented from Warne Chemical and Equipment Company and delivered to the site.
- Miscellaneous pipe and materials to fabricate the wellhead assembly and transfer piping will be purchased locally and fabricated in the field.
- Field measurement equipment and sampling materials will be shipped to the site or mobilized with the 2-PHASE system.

The duration for the setup is estimated to be one week. The following steps will be performed to set up for the pilot test:

- Locate all equipment on the site. Delineate the site to restrict access. Establish a location for vehicles and materials.
- Install extraction well, piezometers, and vapor probes.
- Develop extraction well and take baseline groundwater samples. Develop piezometers to assure communication with the aquifer.

Assemble the wellhead, straw, and fittings necessary for the extraction well and for piezometer and vapor probe measurements.

- Attach and assemble the liquid flow totalizer and vapor flow meter.
- Install a hose from the liquid discharge port of the vacuum system to the activated carbon drum and a hose from the outlet of the carbon drum to the storage tank.
- Connect power from the generator to the 2-PHASE system, test the generator, and test the voltage to the system.
- Test the operation of the 2-PHASE equipment.
- Measure baseline groundwater elevations. Measure groundwater elevations at two background wells for reference purposes.

4.3 Performance of Test

The following steps will be performed during the pilot test.

- Start generator and 2-PHASE system and allow warm-up of 2-PHASE equipment. Check operating conditions during warm-up. Document liquid totalizer reading.
- Attach vacuum hose to system and wellhead. Insert the straw into the well above the water table and take initial soil vapor sample. After taking the vapor sample, lower the straw to evacuate liquid from the well bore. When all liquid is

evacuated, open aspiration air valve and seal the wellhead.

- Ensure proper operation of activated carbon treatment train and filling of storage tank.

- Adjust aspiration air valve to minimize aspiration air flow and maximize vacuum applied to the well. Check operating conditions of the 2-PHASE system.

- Perform field measurements, record operational data, and take liquid and vapor samples according to the schedule in the sampling and analytical plan.

- Optimize aspiration of extracted liquid, applied vacuum, and operating conditions for the remainder of test. Monitor the fill rate of liquid storage tanks. Maintain fuel level in generator. Run continuously at a constant rate for a one-week period.

4.4 System Shutdown and Equipment Demobilization

The following steps will be taken to shut down the 2-PHASE system and prepare for demobilization.

- Document all final operating conditions and field measurements.

- Raise the straw above the water table and collect a final soil vapor sample from well.

- Decontaminate vacuum system and PVC piping by running clean water through the system.

- De-energize the 2-PHASE vacuum system and electric generator. Allow all equipment to come to rest.

- Disconnect the power from the generator.

- Disconnect the vacuum hose, transfer piping, and liquid transfer hose. Seal carbon drum. Remove wellhead assembly from the well.

- Sample groundwater in the well. Cap the well.

- Measure groundwater elevations in background wells to determine area-wide changes during test.

- Collect carbon sample from GAC for characterization.

The following steps will be followed to demobilize equipment and materials from the site.

- Secure the 2-PHASE system and transport to its origin. Return the generator to rental company.

- Remove all tools and equipment from the site.

- Have contracted vac-truck empty storage tank and discharge treated water to on-site WWTP. Return tanks to origin.

- Return activated carbon drum for disposal.

- Perform site inspection with a representative of Base Environmental Office.

5.0 SAMPLING AND ANALYTICAL PLAN

To assess the effectiveness of the 2-PHASE system, field measurements will be performed, system operating conditions will be recorded, and liquid and vapor samples will be taken. The following sections describe the measurements and sampling to be performed and the purpose of these activities.

5.1 Field Measurements

Tables 5-1 and 5-2 will serve as the field data sheets for field measurements and indicate the data to be recorded. Measurements will be taken approximately six times during the first day of each test and four times per day thereafter. Field measurements will indicate the effects of the 2-PHASE system on the subsurface formation and will consist of the following:

- Groundwater levels in the liquid piezometers and monitoring wells to measure drawdown of the static water table;
- Vacuum measurements of the three vapor probes (Pride Hangar only) and piezometers (both sites) to measure the magnitude and extent of vacuum influence; and
- Weather conditions and other comments.

5.2 Operating Conditions

Table 5-3 will serve as the field data sheet for system operating conditions and indicates the data to be recorded. Operating conditions of the 2-PHASE system will be monitored to evaluate the applicability of the technology to the remediation of this and other sites. The operating conditions to be recorded include the following:

- System inlet vacuum and temperature;
- Wellhead residual vacuum and aspiration air flow;
- Seal fluid temperature and pressure;
- Exhaust vapor temperature and pressure;
- Extracted vapor flow rate to evaluate vapor and contaminant extraction rates; spot real-time measurements of total VOCs may also be made with a portable direct-reading instrument;
- Extracted liquid volume to evaluate liquid and contaminant extraction rates;
- Operating time, down time, and repairs; and
- Other comments.

5.3 Sampling

Energy Laboratories Inc. will perform all analyses on liquid samples, including EPA Methods SW-8260 and SW-8015M. Vapor samples will be analyzed by Microseeps at the University of Pittsburgh Applied Research Center by analytical method AM4.02. Supplemental information describing the Microseeps Sampling and Analytical Method is provided in Appendix B.

Soil cuttings from well installation will be characterized using method SW-8015. Carbon will be characterized using the 11 RCRA test.

Table 5-4 will serve as the field data sheet for analytical sampling and indicates the type of sampling to be performed. The purpose of liquid and vapor sampling is to evaluate the extraction of contaminants from the subsurface, characterize wastes, evaluate treatment effectiveness of the carbon system, and facilitate the evaluation of the 2-PHASE technology for the remediation of this and other sites. A description of the sampling to be performed follows:

- Pre- and post-test analyses for VOCs by EPA Methods SW-8260 and SW-8015M will be performed on groundwater from the extraction wells EW-1 and EW-2. Sampling will be performed with a bailer and be in accordance with the QAPP.

Table 5-1. Field Measurements Data Sheet (Pride Hangar)

Date	Time	Water Level (ft below top of casing)					Piezometer Vacuum (in. WC)			Vapor Probe Vacuum (in. WC)			Weather		Comments
		Piezometers		Monitoring Wells (MW)											
		P1	P2	941103	941104	941129	P1	P2	941103	V1	V2	V3	Temp (°F)	Baro. (mb)	

Table 5-2. Field Measurements Data Sheet (BG-04)

Date	Time	Water Level (ft below top of casing)					Piezometer Vacuum (in. WC)			Weather		Comments
		Piezometers			Monitoring Wells (MW)							
		P1	P2	P3	941148	93BG04	P1	P2	P3	Temp (°F)	Baro. (mb)	

Table 5-3. 2-PHASE System Operating Conditions Data Sheet

			System Inlet		Wellhead		Seal Fluid				Exhaust Vapor					
Date	Time	Total Oper. Hours	Temp (°F)	Vacuum (In. Hg)	Top of Straw Vac. (In. Hg)	Well Vac. (In. Hg)	Temp (°F)	Press. at Pump (psi)	Oil Pot Temp. (EF)	Oil Pot Press. (psi)	Temp. (°F)	Press. (psi)	Flow (cfm)	Aspir. Flow (cfm)	Totalizer Liquid Vol. (gal.)	Comments

Table 5-4. Analytical Sampling Field Data Sheet

Schedule		Extracted Liquid	Extracted Vapor	Liquid Duplicate	Vapor Duplicate	Soil Cuttings	Activated Carbon	Groundwater	Soil Vapor	Liquid Phase Carbon Effluent (Storage Tank)
Day	Time	SW-8260/8015M	AM4.02	SW-8260/8015M	AM4.02	SW-8015	11 RCRA Test	SW-8260/8015M	AM4.02	SW-8260
0	Before					X		X	X	
1	0.25	X	X							
1	4	X	X							
1	8	X	X							X
2	24	X	X							
2	28	X								
2	32	X	X	X	X					
3	48	X	X							
3	52	X								
3	56	X	X							
4	72	X	X	X	X					
4	76	X								
4	80	X	X							
5	96	X	X							
5	100	X								
5	104	X	X							
6	120	X	X							
6	128	X								
7	144	X	X							
7	148	X								
7	After						X	X	X	

- Pre- and post-test analyses for VOCs by method AM4.02 will be performed on vapor samples from EW-1 and EW-2. These samples will be collected by operating the 2-PHASE system with the straw above the water table so that only soil gases are extracted.

- Nineteen extracted groundwater samples (2-PHASE effluent prior to carbon treatment) will be taken over each test period and will be analyzed for VOCs by EPA Methods SW-8260 and SW-8015M to facilitate evaluation of the 2-PHASE system. In addition to the 19 groundwater samples, 2 duplicate groundwater samples and 1 trip blank will be analyzed for sample quality assurance/quality control (QA/QC).

- Thirteen extracted vapor samples (vapor discharge from 2-PHASE system) will be taken over each test period and will be analyzed for VOCs by method AM4.02 to facilitate evaluation of the 2-PHASE system. In addition to the 13 vapor samples, 2 duplicate vapor samples and 1 trip blank will be analyzed for sample QA/QC. Method AM4.02 involves collecting sample vapor with a syringe and injecting the sample into an evacuated 22-cc sample vial to approximately 1 atmosphere positive pressure (approximately 44-cc sample), as described in Appendix A. Because of the altitude difference between the Base (Rapid City, South Dakota) and the laboratory (Pittsburgh, Pennsylvania), approximately 50 cc of sample will be injected at this site.

- A treated groundwater sample will be taken from the liquid phase carbon drum effluent and analyzed for VOCs by EPA Method SW-8260 to evaluate the presence of contaminants prior to discharge of the treated groundwater. These samples will be analyzed by Energy Laboratories with rapid turnaround time so that data can be obtained prior to demobilization.

6.0 REPORTING

At the conclusion of the pilot-scale test, a Technology Evaluation Report will be prepared summarizing the results of the study. One report will be prepared for each site. The report will include a discussion of the site background, the equipment design and testing apparatus, analytical data and quality of data for extracted liquid and vapor, groundwater drawdown, extent and magnitude of vacuum influence, liquid and vapor flow rates, contaminant removal estimates, treated liquid and vapor contaminant concentrations, and boring logs.

Contaminant removal rates and the total mass of contaminants removed from the subsurface will be calculated using extracted vapor and liquid flow rate data and average dynamic contaminant concentrations. This information will be used to discuss the remedial effectiveness of the 2-PHASE technology and forecast removal rates for future use of the technology.

Data describing the extent and magnitude of vacuum influence relative to the distance from the extraction well will be used along with groundwater drawdown data to refine design criteria for well spacing and contaminant removal effectiveness for future remedial designs.

Operational data for the 2-PHASE system and test apparatus will be used to discuss the technical feasibility of the 2-PHASE technology and develop criteria for full-scale application of the technology.

The Technology Evaluation Reports for the 2-PHASE pilot tests at Ellsworth AFB OU-11 and the results of similar tests at other ACC sites will be used for the PREECA. The results of these pilot studies will be used to evaluate vacuum-enhanced two-phase extraction for the remediation of these and other ACC sites, develop site-specific action memoranda, and support meetings and discussions of the PREECA for vacuum-enhanced two-phase extraction.

7.0 RESIDUALS MANAGEMENT

At the conclusion of the test, there will be one drum of liquid phase activated carbon; a tank of treated water; drill cuttings from extraction well, piezometer, and vapor probe installation; purge water from sampling and well development activities; and miscellaneous materials for disposal.

The activated carbon drums will be disposed of as hazardous waste. This will be manifested by the Base. The carbon will be characterized as described in Section 5.

The treated groundwater in the storage tank will be sampled for VOCs during the test. Upon completion of the analyses, and given acceptable concentrations, the water will be discharged to the base WWTP. Ricer Company will use a 3380-gal. vac-truck to empty water from the tank, haul it to the WWTP, and discharge the water. This activity will take approximately one day. After the tank is empty, it will be transported back to Warne Chemical and Equipment Company. Since the water contained in the tank will have been fully treated and carbon polished, tank decontamination will not be necessary.

Drill cuttings and purge water will be drummed at the site. Approximately 10 drums are expected. Cuttings will be characterized as described in Section 5 and disposed of properly. Purge water will be treated at the site using the activated carbon.

When the test is completed, there will be some PVC pipe from the test apparatus for disposal. This includes the wellhead assembly and the transfer piping from the 2-PHASE system to the liquid phase carbon. These materials will be decontaminated by rinsing with clean water. Disposable personal protective equipment (e.g., sampling gloves; tyvek coveralls, if used) are not expected to contain significant contamination. The Ellsworth AFB Remedial Project Manager will be contacted to coordinate the disposal of this material at a local landfill.

8.0 SITE SAFETY AND HEALTH PLAN (SSHP)

This SSHP provides guidance for conducting field activities on a pilot test of the 2-PHASE vacuum extraction to be conducted at Ellsworth AFB. The major components of the plan include project organization, hazard analysis, personal protective equipment (PPE), work areas, and emergency procedures. This SSHP must be available on site as a reference. It is expressly intended that project work be guided by applicable sections of the Occupational Safety and Health Administration (OSHA) standards for general industry [29 Code of Federal Regulations (CFR) 1910] and for the construction industry (29 CFR 1926).

The tasks to be conducted during this project are as follows:

- Mobilize project equipment;
- Install wells;
- Set up equipment and piping;
- Perform 2-PHASE vacuum extraction and collect associated data; and
- Demobilize equipment and piping.

8.1 Project Organization and Health and Safety Responsibilities

This section outlines the project organization and health and safety responsibilities of the team.

8.1.1 Project Manager

Mr. Fran Slavich, P.E., has overall responsibility to ensure that this SSHP is implemented in accordance with federal, state, and local community requirements, as well as with Radian policy.

8.1.2 On-Site Engineer/Safety Officer

Mr. James Machin, P.E., shall be responsible for on-site health and safety observations and recommendations and for ensuring that this SSHP is followed. Mr. Machin will have authority to stop the project on the basis of his observation of health and safety concerns. Additional duties and/or responsibilities of the engineer are as follows:

- Ensure that this plan is read and understood by field personnel prior to beginning the project;
- Locate support facilities outside the work area;
- Conduct and/or observe air monitoring instrumentation and ensure availability of applicable PPE;
- Ensure that personnel observe safe work practices in accordance with this SSHP;
- Maintain safety equipment;
- Initiate emergency phone calls if an injury or accident requires medical attention;
- Upgrade the conditions of this plan as indicated by site conditions or changes in the scope of work;
- Report problems to the appropriate supervisor and project health and safety officer;
- Maintain the project health and safety file; and
- Conduct daily safety briefings with all site personnel.

8.1.3 Field Team Members

Members of the field team are responsible for reading and understanding the SSHP, performing work safely, being aware and alert of signs of exposure to contaminants and/or heat

stress, and reporting any unsafe working conditions to their immediate supervisors.

8.1.4 Project Health and Safety Officer

Mr. Kim Worl, CIH, will serve as this project's health and safety officer. Mr. Worl will not participate in on-site work but will be available to assist the on-site engineer/safety officer via telephone.

8.2 Hazard Analysis

This section of the SSHP addresses potential on-site hazards that may be encountered during the activities described below. This section discusses tasks that will be performed and associated risks that may be encountered.

8.2.1 General Safety

The presence of heavy equipment, moving/ rotating parts, and multiple pieces of equipment while mobilizing and demobilizing can contribute to potential hazards. Prior to the operation of any machinery, all belt and coupling guards associated with motorized equipment will be in place and secured. Personnel should not place anything behind a guard.

When spotting trailer-mounted equipment, wheels will be blocked to prevent movement.

During the planning/mobilization phase of the program, Base personnel shall be consulted about the location of utility lines and other such underground hazards and obtain all Ellsworth AFB-required permits. If excavation or drilling cuttings indicate the possible presence of underground drums or cylinders, operations shall be stopped immediately.

8.2.2 Mechanical Hazards

Hazards while working with mechanical equipment can include cuts, contusions, being struck by or striking objects, being caught between objects, becoming entwined in rotating tools, and falling objects. Care should be taken to eliminate these potential hazards by ensuring that mechanical safeguards are in place, that safe distances between personnel and moving parts are maintained, and that personnel avoid areas where vehicles and equipment are being moved or positioned.

Potential burn hazards exist with the hot oil reservoir on the 2-Phase equipment and exhaust from the generator. Care will be taken around this equipment, and work gloves will be worn to protect from direct contact.

8.2.3 Electrical Hazards

Proper lock-out/tag-out procedures shall be used whenever work is performed on the 2-PHASE unit per Section 6.2 of the Radian Corporate Health and Safety Manual. Electric shock can occur by direct contact with live wires or with electrical equipment and instruments that are wet or have faulty wiring. Any extension cords used with the equipment should be checked prior to use for cuts or loose connections in the coating protecting the wires.

8.2.4 Slips, Trips, and Fall Hazards

Areas may be muddy and have uneven surfaces. Team members shall be aware of these and other possible hazards, such as equipment on the ground. Falls can occur when climbing ladders on frac tanks. Personnel should always have three points of contact while climbing ladders. If heavy or bulky equipment is needed on the top of the tank, it should be tied to a rope and lifted from below. Railings should be available on the top of frac tanks.

8.2.5 Fire Hazard

Fires may be caused by excavation of buried gas lines, grass fires, and equipment fires. Precautions should be taken to minimize the potential for fires. No smoking is allowed inside the work area.

8.2.6 Gas and Power Lines

Underground utility lines present in the area shall be located and marked to prevent accidental puncture or breakage during excavation or drilling activities. All contacts (regarding the location of buried lines) with Base and utility company personnel shall be documented. In the event an unmarked buried utility line is damaged, work operations shall halt immediately and all equipment be shut down until the nature of the line is discovered. Should damage occur to a natural gas utility line, all electrical and motorized equipment shall remain shut down, and the contractor shall be responsible for having the line repaired immediately.

8.2.7 Heavy Equipment

The presence of heavy equipment on site requires that all personnel be constantly aware of the location, speed, and direction of the equipment. To help ensure that employees are aware of this in the area, all equipment shall have backup alarms that operate properly. When working around heavy machinery, employees must make their presence known to the equipment operators. All moving equipment shall consist of road-legal vehicles and shall observe all the traffic regulations at Ellsworth AFB. Maintenance shall be conducted on a routine (as needed) basis at the work site or staging area. The work site shall be cordoned off with yellow tape and/or reflective safety flagging to prevent vehicle or pedestrian interference with the work site. Work shall not impede normal traffic ways without providing orange traffic cones to direct traffic around the working site.

8.2.8 Noise

Work around heavy equipment can result in exposure to excessive noise. Operation of the 2-PHASE equipment normally does not result in noise levels in excess of the OSHA-permissible exposure limit of 90 dBA or the action limit of 85 dBA. The electric generator operating on site may result in high noise levels and may result in communication difficulties and hearing impairment. It is not anticipated that hearing protection will be needed; however, ear plugs will be available to employees.

8.2.9 Heat Stress

Working in elevated temperatures while wearing PPE may lead to heat stress in the form of heat exhaustion and/or heat stroke. Symptoms of heat exhaustion include dizziness, light-headedness, slurred speech, fatigue, copious perspiration, cool clammy skin, and an increased resting heart rate (110 beats/minute). Symptoms of heat stroke include delirium, fainting, and hot, dry, flushed skin. Heat stroke is a life-threatening condition, and immediate medical attention is required if any symptoms of heat stroke are observed. Heat stress monitoring and prevention procedures will be initiated when ambient temperatures exceed 90°F. Heat stress reduction procedures shall consist of the following:

- Potable water and/or Gatorade™ will be made available to the field team throughout the work day. Field personnel will be encouraged to drink fluids frequently. Field teams working outdoors continuously should break for water at least every hour.

- When temperatures exceed 90°F, all field personnel working outdoors will measure their heart rate at least hourly. If the heart rate exceeds 110 beats/minute, the individual will rest for 10 minutes and drink fluids throughout the rest period. The heart rate should again be measured at the end of the rest period. If the heart rate has dropped below 110 beats/minute, the individual may return to work. If the heart rate exceeds 110 beats/minute, contact the on-site engineer responsible for health and safety.

- Any personnel displaying signs or symptoms of heat stress will stop work and rest for at least 15 minutes. If symptoms persist beyond this rest period, the on-site engineer responsible for health and safety will be contacted. Personnel displaying symptoms of heat stroke, the most serious

type of heat-related illness, should immediately be taken to the closest medical facility.

8.2.10 Chemical Hazards

Volatile chemicals identified in the soil and groundwater at the OU-11 site in concentrations that have the potential for employee exposures are listed in Table 8-1. The table also lists standards and guidelines for employee exposure and relevant health effects.

Significantly contaminated soils and groundwater, if encountered, will produce elevated airborne concentrations and elevated point source concentrations that are readily detected with direct-reading instruments.

Inhalation of volatile organic vapors and skin contact with contaminated soils, groundwater, and equipment are the most likely routes of personnel exposure in the work area. Real-time air monitoring instruments will indicate the presence of vapors.

The 2-PHASE system extracts soil vapor and groundwater from the well using a high-vacuum pump. The vapor and liquid phases are separated at the unit. The liquids are passed through aqueous phase carbon before being diverted to a storage tank. The vapors pass through either a carbon bed prior to release to the atmosphere or directly to the atmosphere. Worker exposure to chemical contaminants—if the system is operating as designed—is expected to be minimal. The following safety precautions will be implemented to ensure the protection of employees from potential chemical hazards:

- An air monitoring program, described in Section 8.4, will be implemented in order to measure airborne concentrations of VOCs potentially encountered during on-site work;
- PPE will be provided and required to be worn;
- Chemical-resistant protective clothing and respiratory protection will be available in the event that air monitoring instruments indicate the presence of vapors above 10 ppm in the breathing zone of employees; and
- Any chemicals being brought onto the site will have associated Material Safety Data Sheets, which will be reviewed with and available to the field team.

8.3 Personal Protective Equipment

The minimum required PPE for all personnel on site during the 2-PHASE treatability study includes the following:

- Hard hat;
- Safety glasses with side shields;
- Steel-toed work boots: leather (rubber if liquid contamination exists);
- Work gloves; and
- Hearing protection (when noise levels exceed 85 dBA).

The following additional PPE will be available on site:

- Chemical-resistant clothing: disposable Tyvek® coveralls (coated Tyvek® shall be used in wet areas), disposable nitrile gloves; and
- Half-face or full-face respirator with organic vapor/high-efficiency particulate air cartridges.

PPE shall be used by personnel when engineering controls and work practices are not adequate to reduce employee exposures to acceptable levels. PPE selection shall be based on specific task activities, historical data of contaminants known to exist at the site, site conditions, and the results of the air monitoring program described in Table 8-2. The scope of this section is strictly limited to the activities described in Section 8.0. Real-time air

Table 8-1. Ellsworth AFB Potential Chemical Hazards

Contaminant	Groundwater Concentraction at Site (μg/L)	OSHA PEL (ppmv)	ACGIH TLV (ppmv)	Acute Effects of Exposure	Skin Designation[a]	Known or Suspected Human Carcinogen
Chloroform	200	50	10	narcosis, headaches, fatigue, skin irritation		✓
1,2-Dichloroethylene	35	200	200	CNS depressant, eye and respiratory irritation		
Trichloroethylene	7000	100	50	eye irritation, nausea, tremor		

[a]A "skin designation" indicates that the dermal route may contribute significantly to the overall exposure. These compounds are readily absorbed by the skin, and extra precautions are necessary to prevent skin contact.

ACGIH TLV = American Conference of Government Industrial Hygienists Threshold Limit Value
CNS = Central Nervous System
OSHA PEL = Occupational Safety and Health Administration Permissible Exposure Limit (28 CR 1910.1000)

Table 8-2. Hydrocarbon Response Criteria

Organic Vapor Concentrations and Specific Contaminant Monitoring	Sampling Frequency	Action Taken
OVC < 10 ppm for >2 minutes	Every hour thereafter or upon recommendation of the health and safety officer	Continue work with required minimum PPE for the field activity.
OVC 11-100 ppm for >2 minutes	Every 15 minutes	All personnel on site will don half-face or full-face air-purifying respirator equipped with organic vapor/HEPA filter cartridges. All personnel on site will don Tyvek® coveralls.
OVC 101-500 pmm >2 minutes	Every 10 minutes	All personnel on site will don full-face air purifying respirator equipped with organic vapor/HEPA filter cartridges.
OVC >500 ppm		Stop work. Work crews position themselves upwind of site. Reevaluate in 15 minutes. Contact field coordinator and project health and safety officer. NOTE: These same actions are to be taken if lower explosive limit is >20%.

HEPA = high-efficiency particulate air
OVC = organic vapor concentration
PPE = personal protective equipment

monitoring results may require an immediate upgrade in respiratory protection or cessation of work activities until hazardous vapor concentrations disperse. Specific guidance is provided in Table 8-2.

The major chemical exposure hazards at the site result from the following:

- Inhalation of airborne contaminants either in the form of dust or fugitive vapors emanating from the contaminated soils, liquids, or the carbon treatment vessels; and

- Dermal contact with, or ingestion of, contaminated soils and liquids.

PPE requirements for each task may be modified after the on-site and project safety officers discuss and concur. Guidance regarding PPE inspection and respirator cartridge replacement frequency can be found in the Ellsworth AFB SSHP.

8.3.1 Temperature Limitations

Chemical-resistant clothing and respirator use can cause employees to fatigue rapidly and will inhibit body cooling. Personnel shall be instructed to pace themselves to ensure adequate rest periods.

8.3.2 Training and Medical Surveillance Requirements

All personnel are required to be in compliance with OSHA 29 CFR 1910.120, Hazardous Waste Operations Health and Safety Training Requirements. All field team personnel must have had a physical examination with medical clearance within the last year to conduct this work.

8.3.3 Record-Keeping Requirements

Records of training and medical surveillance shall be maintained for the project records.

8.4 Air Monitoring and Safe Work Practices

8.4.1 Air Monitoring

Air monitoring will be performed at the outlet of the system and in the breathing zone of the field team to determine the potential for worker exposure. Monitoring will be performed in the breathing zone of the worker nearest the source(s) of air contaminants and their discharge to the atmosphere. The following precautions will be taken in order to ensure that field personnel are not being overexposed to organic vapors.

- If discharging extracted vapors directly to atmosphere, the extraction system will be equipped with an exhaust stack that is at least 8 feet above grade; and

- All work associated with the extraction testing will be performed upwind of the exhaust stack whenever possible.

8.4.2 Organic Vapor Concentration

Organic vapor concentrations will be measured with a photoionization detector and direct-reading detector tubes. Table 8-2 summarizes the actions that will be taken in response to monitoring results.

8.5 Work Zones and Decontamination Procedures

The on-site engineer/safety officer is responsible for establishing the appropriate work zone designation and defining the zone in accordance with this plan.

8.5.1 General Work Zone

A general work zone shall be delineated by the on-site field engineer/safety officer through the use of barricade tape or other appropriate barrier. A general work zone is characterized by an absence of uncontrolled chemical substances or materials.

8.5.2 Exclusion Zone

An exclusion zone (EZ) shall be established to minimize the risk of chemical exposure and contaminant migration off site and to restrict unauthorized personnel from entering potentially dangerous work areas. No eating, drinking, or smoking shall be allowed in the EZ. The EZ will be established using barricade tape.

8.5.3 Contamination Reduction Zone

A contamination reduction zone acts as a buffer zone allowing personnel egress to and from the EZ. All contaminated clothing and equipment is disposed of or decontaminated in this zone.

8.5.4 Support Zone

A support zone will be established outside of the EZ. This zone is considered free of chemical and physical hazards and may be used for observational purposes.

8.5.5 Decontamination Procedures

Decontamination of equipment shall be conducted in the general work area. This includes decontaminating or isolating equipment before placing it in sampling vehicles. Decontamination of sampling equipment shall occur before removing PPE. Due to the nature of the site and the scope of work, it is not expected that decontamination of PPE or personnel will be needed to protect worker health. If personnel come in contact with groundwater, the affected area should be thoroughly washed with soap and water.

8.6 Emergency Response

Emergency procedures listed in this plan are designed to instruct the field team in handling medical emergencies.

8.6.1 Injuries

Medical problems that may occur on site need to be handled competently and quickly. Each field team member shall know the location and contents of the first aid kit supplied to them. Each field team member shall be aware of the instructions and information given below.

- Know the emergency telephone numbers in Table 8-3.
- Seek professional medical attention for personnel who are not breathing, bleeding severely, experiencing intense pain, or unconscious. Each member of the site team will know how to call for an ambulance (on and off base).
- Chemicals or dust that get in the eyes should be flushed out with water for 15 minutes.
- Do not remove objects that are stuck in the eye. Always seek medical attention for eye injuries.
- All burns (chemical or thermal) will be treated by running cold water over the affected area.
- Report all injuries to the project safety officer and/or supervisor.
- In case of any emergency, Ellsworth AFB Environmental Management must be notified.

8.6.2 Emergency Equipment

The following emergency equipment shall be available for immediate use. All field personnel shall be made aware of the location of the emergency equipment.

- Phone list and directions to the nearest emergency care center;
- First aid kit;
- One 10-lb ABC-rated fire extinguisher;
- Eye-wash station; and
- Five gal. of potable water.

Table 8-3. Emergency Phone Numbers

Emergency Agency	Phone Number
Base Contacts: Dell Petersen John DeYoe Larry Amburn	(605) 385-2675 (605) 385-2680 (605) 385-2680
Police	4001
Fire Response	On-Base 117 Off-Base 911
Ambulance	7629
Hospital: Ellsworth AFB Hospital - 28th Medical Group Eleventh Street	7630 3534 information
Rapid City Regional Hospital 353 Fairmont Road Rapid City, South Dakota	(605) 341-1000
Medical Emergency 24-hour Toxicological Information Service	(513) 421-3063
Center for Disease Control	(404) 639-3311
CHEMTREC	(800) 424-9300
Project Health and Safety Officer: Kim Worl, CIH	(916) 362-5332

8.6.3 Emergency Phone List

Table 8-3 is a list of emergency phone numbers.

8.6.4 Hospital Directions

A map to the local city hospital is provided in Figure 8-1.

The local city hospital address is:

Rapid City Regional Hospital
353 Fairmont Road
Rapid City, South Dakota

The Base hospital is located on Eleventh Street.

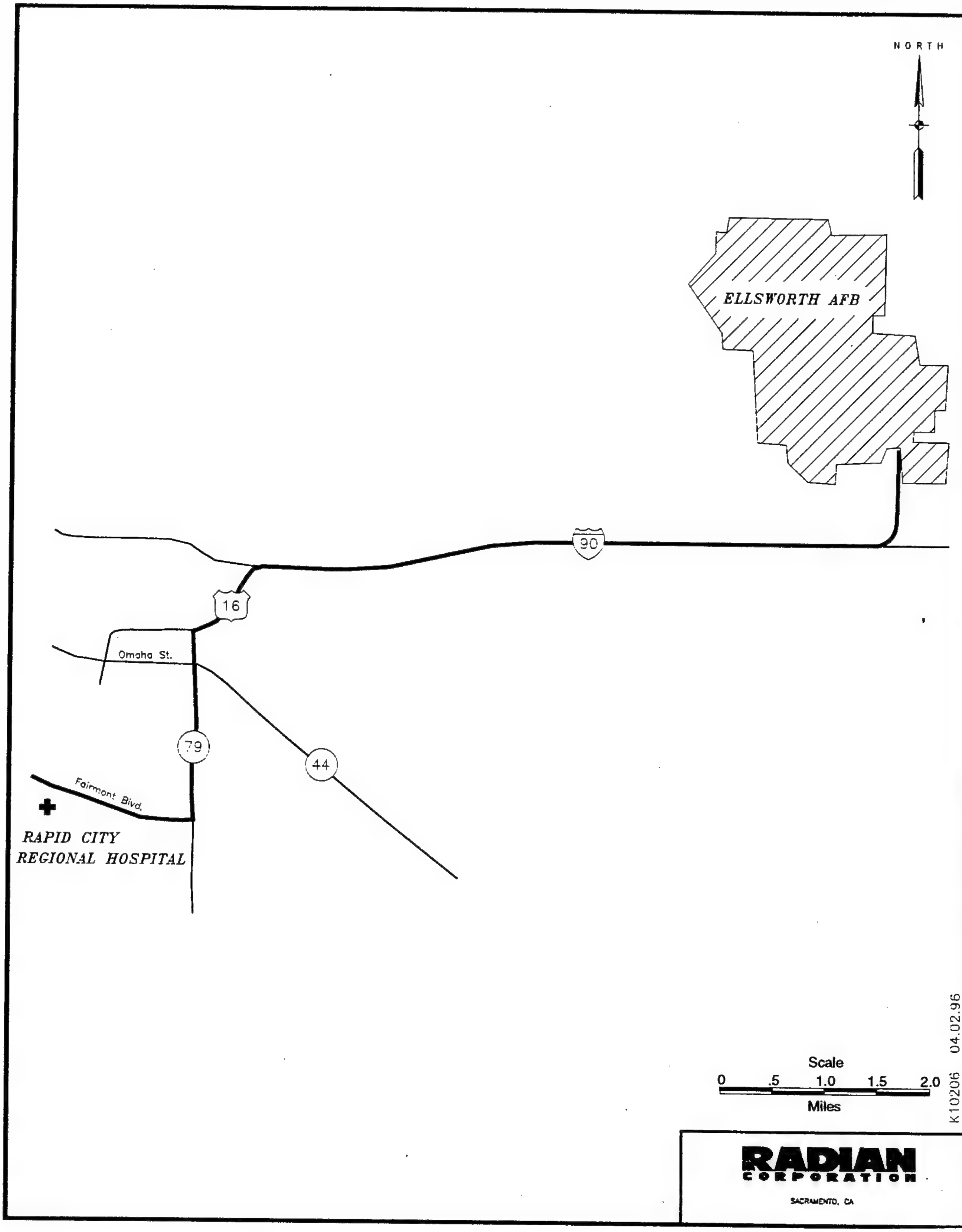


Figure 8-1. Map to Local City Hospital

9.0 SCHEDULE

The schedule for all activities related to this pilot-scale test is presented in Table 9-1. The schedule includes anticipated task start dates and task completion dates, as well as a relative scale of time in the event of an unforeseen change in the schedule.

Table 9-1. Ellsworth OU 11 2-PHASE Extraction Pilot Test Schedule

Activity	Start Date	Completion Date	Cumulative Work Days From Notice to Proceed to Task Completion
Prepare and submit work plan	28 March	12 April	15
Receive work plan comments	12 April	26 April	30
Complete and submit final work plan	26 April	6 May	40
Order/reserve: carbon drum, generator, tank, sampling and measurement equipment	12 April	6 May	40
Install vapor probes and piezometers	6 May	10 May	44
Mobilize equipment	3 May	10 May	44
Set up for test	10 May	11 May	45
Run tests	11 May	25 May	59
Dismantle apparatus	25 May	26 May	60
Discharge water and return storage tank	25 May	26 May	60
Demobilize equipment and materials	26 May	27 May	61
Disposal of carbon drum and soil residuals	27 May	25 June	90
Review field and analytical data	27 May	25 June	90
Prepare and submit draft Technology Evaluation Reports: Ellsworth AFB	25 June	26 July	121
Receive comments	26 July	16 August	142
Prepare and submit final Technology Evaluation Reports	16 August	30 August	154

Note: All dates are in 1996.

10.0 REFERENCES

EA Engineering, Science, and Technology. *Remedial Investigation Report, 0U-11, Ellsworth AFB, SD*, September 1995.

Rust Environment and Infrastructure. *Technical Memorandum, Summary and Recommendations for Further Characterization of TCE Contamination at BG-04, Ellsworth AFB, SD*, 6 November 1995.

Rust Environment and Infrastructure. *Seismic Refraction Survey, BG-04/TCE Investigation, Ellsworth AFB, SD*, January 1996.

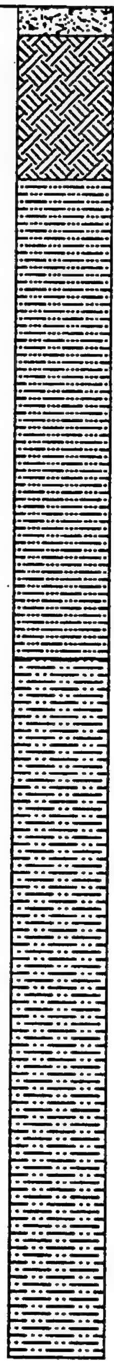
APPENDIX A

Well Logs

SOIL BORING NO: SB941103

SOIL BORING LITHOLOGY DIAGRAM

Depth (ft) | Elevation (ft)



Depth (ft)	Lithology	Description	Elevation (ft)
0	Asphalt	ASPHALT. PID = 21.4 0.00 ft – 0.50 ft Depth.	3212.0
	Fill	HARDFILL. PID = 21.4 0.50 ft – 3.00 ft Depth.	3210
5	Silt & Clay	(ML) – OLIVE (5Y 4/4) CLAYEY SILT, 55% SILT, 45% CLAY, >5% CARBONATE POCKETS, PRODUCT STAINING PRESENT AT INTERFACE, SL MOIST. PID = 18.7 3.00 ft – 9.00 ft Depth.	3205
10		NO RCOVERY. PID = 0.3 9.00 ft – 11.50 ft Depth.	
		(SC) – BROWN (7.5YR 4/4) SAND/CLAYEY SAND, W/ 15% V COARSE, SUB-A TO SUB-R GRAVEL; THE SAND IS 30% FINE, 70% M-C; MOD SORTED, CLAY IS PLASTIC, MOIST. PID = 0.7 11.50 ft – 14.00 ft Depth.	3200
15		NO RECOVERY. PID = N/A. 14.00 ft – 16.00 ft Depth.	
	Sand & Clay	(SC) – OLIVE (5Y 4/4) SAND/CLAYEY SAND--SAME AS 11.5–14 FT INTERVAL, SL MOIST. PID = 0.3 16.00 ft – 19.00 ft Depth.	3195
20		NO RECOVERY. PID = N/A 19.00 ft – 22.00 ft Depth.	
		(SC) – SAND/CLAYEY SAND--SAME AS 16–19 FT INTERVAL. WATER ENCOUNTERED AT 21.8 FT. PID = 0.7 21.00 ft – 24.00 ft Depth.	3190

Boring Completion Date

ELLSWORTH AIR FORCE BASE

Coordinates E: 1156213.97
N: 129899.42

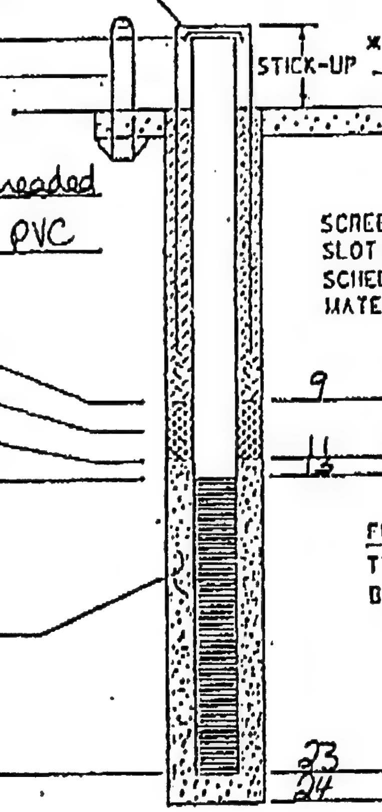
PROJECT MGR	DESIGNED BY	DRAWN BY	CHECKED BY	SCALE	DATE	PROJECT NO	FIGURE
RT	HLB	TRB/MG	HLB	NONE	AUG/95	60378.90	

Entered 8/3/94

DATE GROUTED: 7-27-94	MONITORING WELL: MW941103
DRILLING SUB: HUNTINGTON	
ELEVATION GROUND WATER 21.8'	PROJECT EAFB OU-1 60378.90
DATE INSTALLED 7/25/94 · STARTED 7/25/94 · COMPLETED	LOCATION (Coordinates or Station) SE corner of Pride Hanger
ELEVATION TOP OF HOLE	SIGNATURE OF INSPECTOR Sami Goldman
TOTAL DEPTH OF HOLE 24'	HOLE NO. (as shown on drawing title and file number) SB941103

MONITORING WELL CONSTRUCTION DIAGRAM

(ALL MEASUREMENTS FROM GROUND SURFACE)



PROTECTIVE CASING

TYPE OF PROTECTIVE CASING: Steel

TOP OF WELL

STICK-UP * 2.8 FLUSH MOUNT

GROUND SURFACE

PROTECTIVE POSTS

CASING DIAMETER: 4.0"

TYPE OF PIPE JOINTS: Threaded

TYPE OF BLANK CASING: PVC

LENGTH OF SOLID PIPE 15.8 ft.

SCREEN INFORMATION

SCREEN DIA.: 2.0"

SLOT WIDTH: 0.010"

SCHEDULE: 40

MATERIAL: ☐ PVC ☒ STAINLESS STEEL ☐ OTHER (DESCRIBE)

TOP OF SEAL 9 ft.

TYPE OF SEAL:

TOP OF FILTERPACK 11 ft.

TOP OF SCREEN 13 ft.

FILTERPACK MATERIAL

TYPE:

BACKFILL METHOD:

FILTERPACK

WELL SCREEN LENGTH 10 ft.

BOTTOM OF WELL

23 ft. BOTTOM OF WELL

24 ft. TOTAL DEPTH OF HOLE

WATER LEVEL SUMMARY

READING	DATE	TIME	LEVEL	WATER LEVEL MESUREMENT REFERENCE
1	7/25/94		21.8	TOC TOBH
2				TOC TOBH
3				TOC TOBH

DEPTH FROM TOP OF CASING AFTER DEVELOPMENT:

4

WELL DEVELOPMENT

SEE WELL DEVELOPMENT DATA SHEET

EA ENGINEERING AT ELLSWORTH AFB
WELL DEVELOPMENT RECORD

Well Designation MW41103 Development Technician J. Smith
Date Grouted ____
Date Development Started 8-1-94 Date development concluded 8-1-94
Length of Sandpack ____
Depth of Well 23.08
Depth to Water 21.75 Depth to NAPL —
Liquid Depth 1.33 x 0.16 = 0.22 (vol. of water in 2" PVC)
Liquid Depth 1.33 x 4.07 = 5.41 (vol. of water in 10" borehole)[1]
Vol. of water in 10" borehole (5.41)- vol. of water in 2" PVC (0.22) = 5.19 (vol. of annular space)

Vol. of annular space (5.19)x 0.30 = (1.56) (vol. of water held in sandpack)
Vol. of water in sandpack (1.56) + vol. of water in 2" PVC (0.22) = (1.78) (one well volume)

WELL VOLUME	GAL	TIME	pH	CONDUCTIVITY uMHOS	TEMP C	TURBIDITY NTU
INITIAL	2	1015	7.48	1490	16.0	>71000
1	4	1038	7.43	1510	15.0	>71000
2	6	1048	7.50	1500	14.9	>71000
3	8	1058	7.51	1500	15.0	>71000
4	10	1107	7.51	1500	14.9	>71000
5	12	1119	7.51	1500	14.9	>71000
6	14	1128	7.56	1510	15.0	>71000
7	16	1139	7.42	1600	15.0	>71000
8	18	1154	7.55	1550	15.0	>71000
9	20	1206	7.51	1510	15.0	>71000
10	22	1219	7.57	1510	14.9	
End	hand	bailing :	surging	complete		

Total number of gallons removed 22 Average pumping rate N/A
Equipment used Hand bailer Number of drums generated ____
Comments: ____

[1] If the height of the sandpack is greater than the liquid depth, use the height of the sandpack to determine the vol. of the 10" borehole.

EA ENGINEERING AT ELLSWORTH AFB
WELL DEVELOPMENT RECORD

Well Designation MW941103 Development Technician J. Smith
Date Grouted
Date Development Started 8-1-94 Date development concluded 8-1-94
Length of Sandpack
Depth of Well
Depth to Water Depth to NAPL
Liquid Depth ______ x 0.16 = ______ (vol. of water in 2" PVC)
Liquid Depth ______ x 4.07 = ______ (vol. of water in 10" borehole)[1]
Vol. of water in 10" borehole (______)- vol. of water in 2" PVC (______) = ______ (vol. of annular space)

Vol. of annular space (______)x 0.30 = (______) (vol. of water held in sandpack)
Vol. of water in sandpack (______) + vol. of water in 2" PVC (______) = (1.78) (one well volume)

WELL VOLUME	GAL	TIME	pH	CONDUCTIVITY uMHOS	TEMP C	TURBIDITY NTU
~~INITIAL~~	22	1315	Begin continuous pumping			
11	24	1320	7.37	1700	19.5	>71000
12	26	1330	7.46	1690	18.7	>71000
14	28	1340	7.38	1630	18.0	4.69
~~8~~ 15	30	1347	7.45	1650	17.8	3.10
Stop	W.L.	21.77'				

Total number of gallons removed 30 Average pumping rate 0.5
Equipment used 2" sub. Grundfos Number of drums generated 1
Comments:

[1] If the height of the sandpack is greater than the liquid depth, use the height of the sandpack to determine the vol. of the 10" borehole.

ELLSWORTH AFB, SOUTH DAKOTA RI 1994

WELL GAUGING, PURGING AND SAMPLING SHEET

WELL INFORMATION

Well No.: MW941103 Date: 15/Aug/94

Gauger: J.L.W. Time: 0900

Well Diameter: 2" Sounding Method: W.L.I

Stickup or Flush Measurement Ref.: T.O.C.

GAUGING AND PURGING

Well Depth: 23.04 Purge Method: 2" Redi Flow

Depth to Liquid: Purge Rate: 0.35 g/m

Depth to Water: 21.72 Purge Time: 0935 → 1030

Liquid Column: 1.32 Purge Volume: 5.28

Liquid Volume: 1.76 x 3

Pump Dry? Describe: No

SAMPLING INFORMATION

Sampler: J. Smith Date: 8/15/94 Time: 1145

Split? No With Whom? —

Type of Sampling Equipment:

Sample Analyte | ~~TPH~~ | ~~TCL VOA~~ | TCL SVOCS | ~~TCL Pest/PCB~~ | Metals Total/Dissolved | Others

P.Glycol + Butyl Carbitol

WATER QUALITY

	GAL	PH	TURBIDITY	CONDUCTIVITY	DISSOLVED OXYGEN	TEMP
Initial:	1.0	6.81	—	1620		18.0
Vol-1:	2.0	6.75	—	1680		19.0
Vol-2:	4.0	6.84	—	1660		19.5
Vol-3:	6.0	6.79	—	1690		19.5
@ Sample:					2.44	

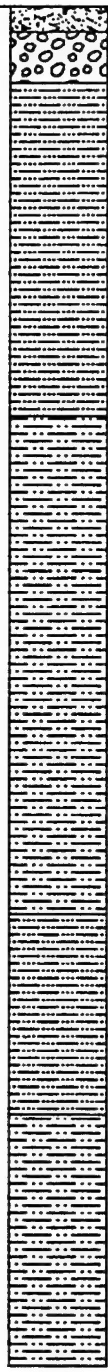
COMMENTS (Well condition, Weather, etc):

8.0	6.86	7.44	1680	19.5
10.0	6.88	6.88	1690	20.0
12.0	6.78	5.95	1670	20.0
14.0	6.81	6.88	1680	20.0
16.0	6.84	5.74	1680	20.0
18.0	6.82	4.69	1690	20.0
20.0	6.89	3.90	1690	20.0

SOIL BORING NO: SB941104

SOIL BORING LITHOLOGY DIAGRAM

Depth (ft) — Elevation (ft)



Depth (ft)	Unit	Description	Elevation (ft)
0	Asphalt	ASPHALT 0.00 ft - 0.50 ft Depth.	3212.0
	Gravel	(GW) - RED (7.5YR 5/6) SUB-BASE AGGREGATE. PID = 74.1 0.50 ft - 1.50 ft Depth.	3210
5	Silt & Clay	(ML) - V DK GREYISH BROWN (10YR 3/2) SILTY CLAY W/ 5% F-SAND; SL MOIST, CARBONATE PRECIP PRESENT THROUGHOUT. PID = 19.3 1.50 ft - 8.00 ft Depth.	3205
10	Sand & Clay	(SC) - YELLOWISH BROWN (10YR 5/6) CLAYEY SAND W/ 5% ROUNDED PEBBLES; MOIST. PID = 3.5 8.00 ft - 15.00 ft Depth.	3200
15		(SC) - YELLOWISH BROWN (10YR 5/6) CLAYEY SAND, 45% GRAVEL, 55% SAND W/ CLAY; DRY, UNCONSOLIDATED, SL HYDROCARBON ODOR AT 16FT. PID = 1.6 15.00 ft - 18.00 ft Depth.	3195
20	Silt & Clay	(CL) - DK YELLOWISH BROWN (10YR 4/4) SILTY CLAY, MOIST, SOFT. PID = 1.6 18.00 ft - 22.00 ft Depth.	3190
25	Sand & Clay	(CL) ~~(SC)~~ - BROWN (10YR 4/3) SANDY CLAY, WET, CLAY HAS HIGH PLASTICITY, FE STAINS THROUGHOUT; 10% SUB-R GRAVEL TOWARD BOTTOM. PID = 1.5 22.00 ft - 27.00 ft Depth.	

Boring Completion Data

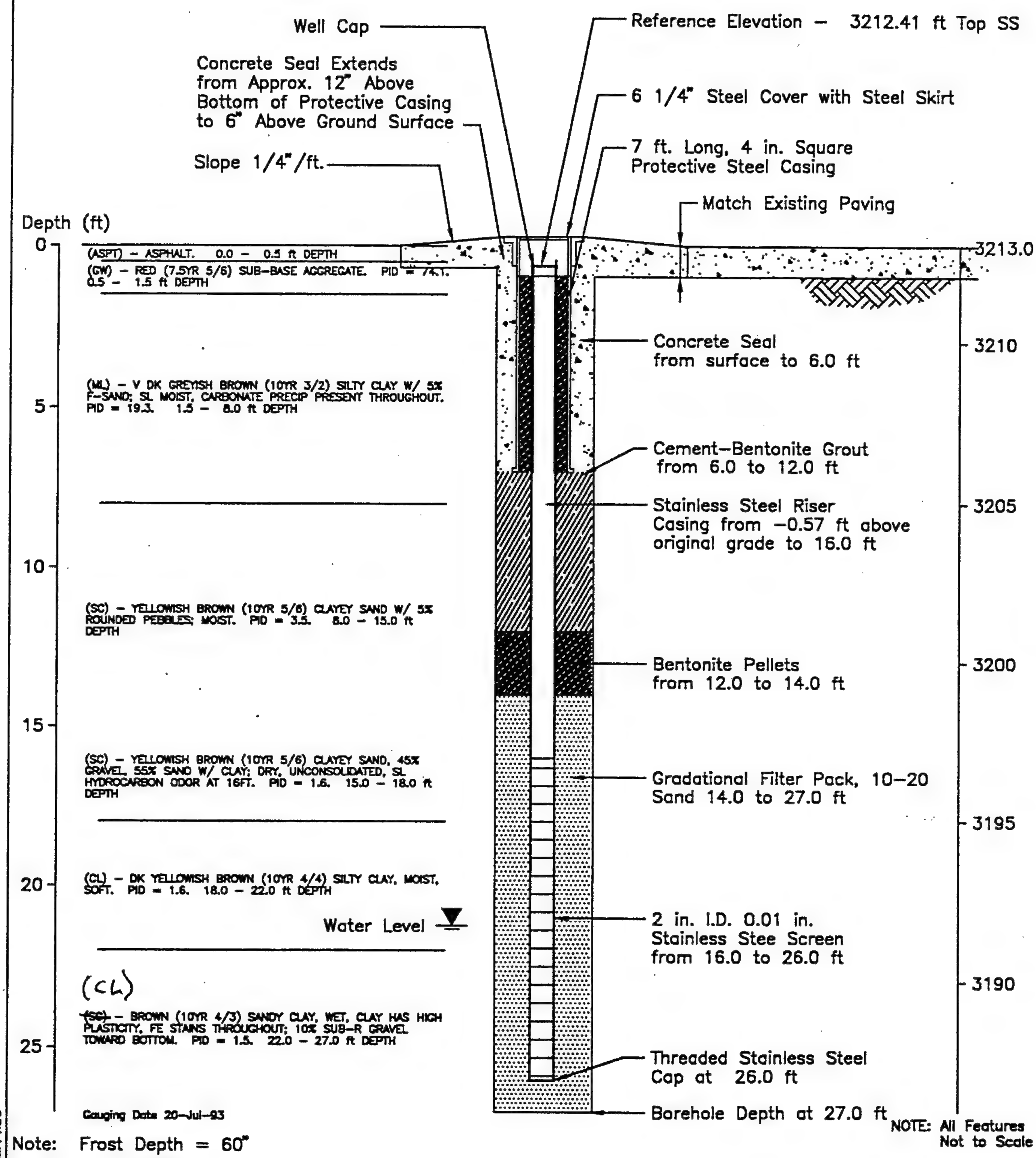
ELLSWORTH AIR FORCE BASE

Coordinates E: 1156003.88
N: 129733.05

PROJECT MGR	DESIGNED BY	DRAWN BY	CHECKED BY	SCALE	DATE	PROJECT NO	FIGURE
RT	HLB	TRB/MG	HLB	NONE	MAY/95	60378.90	

WELL NO: MW941104 (SB941104)

WELL COMPLETION DIAGRAM



Note: Frost Depth = 60"

ELLSWORTH AIR FORCE BASE

Coordinates E: 1156004
N: 129733

PROJECT MGR	DESIGNED BY	DRAWN BY	CHECKED BY	SCALE	DATE	PROJECT NO	FIGURE
RDT	–	HLB/MG	TMO	NONE	OCT 94	60378.90	

DRAWING NAME: F:\HORIZONS\NEW\OU11\WELLS\MW941104
DATE:09/08/1995 TIME:14:30

EA

EA ENGINEERING AT ELLSWORTH AFB
WELL DEVELOPMENT RECORD

Well Designation MW941104 Development Technician J. Smith
Date Grouted
Date Development Started 8-1-94 Date development concluded 8-2-94
Length of Sandpack 13.0'
Depth of Well 25.72
Depth to Water 20.55 Depth to NAPL N/A
Liquid Depth 5.17 x 0.16 = 0.83 (vol. of water in 2" PVC)
Liquid Depth 5.17 x 4.07 = 21.04 (vol. of water in 10" borehole)[1]
Vol. of water in 10" borehole (21.04)- vol. of water in 2" PVC (0.83) = 20.21 (vol. of annular space)

Vol. of annular space (20.21)x 0.30 = (6.06) (vol. of water held in sandpack)
Vol. of water in sandpack (6.06) + vol. of water in 2" PVC (0.83) = (6.89) (one well volume)

WELL VOLUME	GAL	TIME	pH	CONDUCTIVITY uMHOS	TEMP C	TURBIDITY NTU
INITIAL	2	1500	7.58	1700	15.5	>>1000
1	7	1515	7.60	1510	15.0	>>1000
2	14	1526	7.60	1500	14.9	>>1000
3	21	1540	7.57	1500	15.0	>>1000
4	28	1554	7.58	1510	14.9	>>1000
5	35	1604	7.59	1500	13.9	>>1000
6	42	1621	7.52	1510	14.0	>>1000
7	49	1636	7.69	1510	13.5	>>1000
8	56	1659	7.67	1510	14.0	>>1000
Stop hand-bailing & surging						

Total number of gallons removed 56 Average pumping rate N/A
Equipment used Hand bailer Number of drums generated 1
Comments:

[1] If the height of the sandpack is greater than the liquid depth, use the height of the sandpack to determine the vol. of the 10" borehole.

EA ENGINEERING AT ELLSWORTH AFB
WELL DEVELOPMENT RECORD

Well Designation MW941104 Development Technician J. Smith
Date Grouted ______
Date Development Started 8-1-94 Date development concluded 8-2-94
Length of Sandpack ______
Depth of Well ______
Depth to Water ______ Depth to NAPL ______
Liquid Depth ______ x 0.16 = ______ (vol. of water in 2" PVC)
Liquid Depth ______ x 4.07 = ______ (vol. of water in 10" borehole)[1]
Vol. of water in 10" borehole (______)- vol. of water in 2" PVC (______) = ______ (vol. of annular space)

Vol. of annular space (______)x 0.30 = (______) (vol. of water held in sandpack)
Vol. of water in sandpack (______) + vol. of water in 2" PVC (______) = (6.89) (one well volume)

WELL VOLUME	GAL	TIME	pH	CONDUCTIVITY uMHOS	TEMP C	TURBIDITY NTU
INITIAL	2	0835	7.81	1700	18.8	>>1000
1	7	0848	7.28	1580	16.7	151
2	14	0906	7.27	1610	18.0	12.7
3	21	0924	7.29	1690	19.0	6.09
4	28	0940	7.30	1650	19.2	3.56
Stop	W.L.	20.59				

Total number of gallons removed 84 Average pumping rate > 1/2 gpm
Equipment used 2" Sub. Grundfos Number of drums generated 2
Comments: ______

[1] If the height of the sandpack is greater than the liquid depth, use the height of the sandpack to determine the vol. of the 10" borehole.

ELLSWORTH AFB, SOUTH DAKOTA RI 1994

WELL GAUGING, PURGING AND SAMPLING SHEET

WELL INFORMATION

Well No.: MW-94104 Date: Aug/03/94

Gauger: JLW Time: 1505

Well Diameter: 2" Sounding Method: I.F.P.

Stickup or Flush Measurement Ref.: T.O.C

GAUGING AND PURGING

Well Depth: 35.90 Purge Method: HAND BAIL

Depth to Liquid: Purge Rate:

Depth to Water: 30.54 Purge Time:

Liquid Column: 5.36 Purge Volume: 14.5 GAL

Liquid Volume: 7.14

Pump Dry? Describe: NO

SAMPLING INFORMATION

Sampler: J.L.W. Date: AUG/03/94 Time: 1605

Split? NO With Whom?

Type of Sampling Equipment: DISP BAILER

Sample Analyte | TPH | TCL VOA | TCL SVOCS | TCL Pest/PCB | Metals Total/Dissolved | Others

WATER QUALITY

	GAL	PH	TURBIDITY	CONDUCTIVITY	DISSOLVED OXYGEN	TEMP
Initial:						17.5
Vol-1:	7.14	7.03	— — —	1680	3.9	~~[illegible]~~
Vol-2:	14.0	6.68		1680	4.1	16.5
Vol-3:						
@ Sample:						

COMMENTS (Well condition, Weather, etc):

RESAMPLED TO CONFIRM ORIGINAL WATER SCREENING RESULTS.

ELLSWORTH AFB, SOUTH DAKOTA RI 1994

WELL GAUGING, PURGING AND SAMPLING SHEET

WELL INFORMATION

Well No.: MW941104 | Date: 16/AUG/94

Gauger: JLW | Time: 1245

Well Diameter: 2" | Sounding Method: W.L.I.

Stickup or Flush | Measurement Ref.: T.O.C.

GAUGING AND PURGING

Well Depth: 25.70 | Purge Method: 2" REDI-FLOW

Depth to Liquid: | Purge Rate: 0.5 g/m

Depth to Water: 20.57 | Purge Time: 1255 → 1345

Liquid Column: 5.13 | Purge Volume: 21.0

Liquid Volume: 7.0 X 3

Pump Dry? Describe: No

SAMPLING INFORMATION

Sampler: J. Smith | Date: 8-16-94 | Time: 1540

Split? No | With Whom? —

Type of Sampling Equipment: Peristaltic

Sample Analyte: TPH | TCL VOA | TCL SVOCS | TCL Pest/PCB | Metals Total/Dissolved | Others

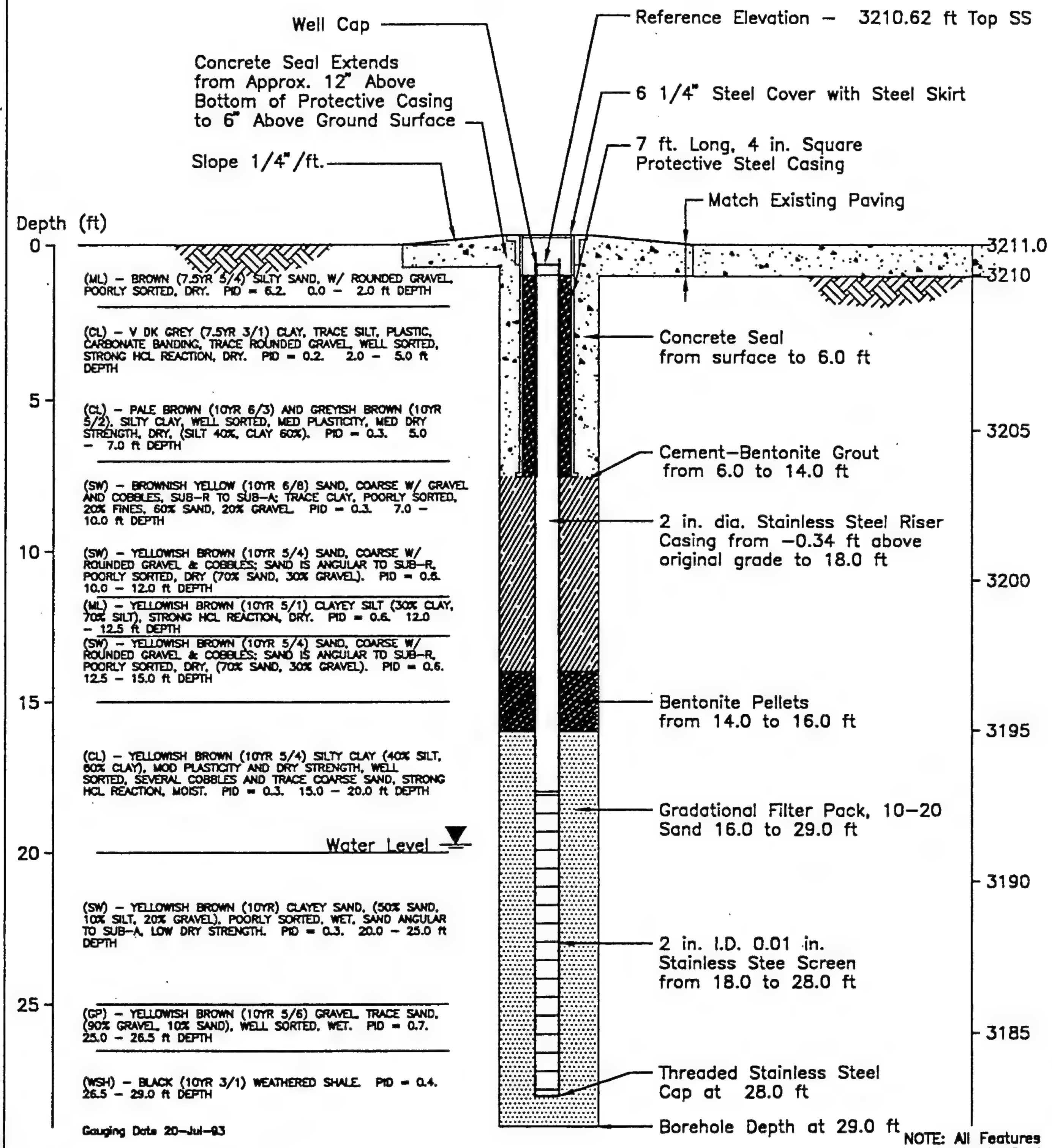
P. glycol + Butyl Carbitol

WELL VOLUME	GAL	TIME	pH	CONDUCTIVITY uMHOS	TEMP C	TURBIDITY NTU
INITIAL	1.0	1258	7.05	1780	21.5	—
	7.0	1308	7.06	1650	19.8	95.3
	14.0	1323	7.09	1620	19.5	23.7
	21.0	1343	7.07	1620	20.0	4.95
	22.0	1504	7.21	1620	16.0	42.6
		1517				12.1
		1520				3.18

D.O. ⇒ 5.63

WELL NO: MW941129

WELL COMPLETION DIAGRAM



NOTE: All Features Not to Scale

Note: Frost Depth = 60"

ELLSWORTH AIR FORCE BASE

Coordinates E: 1156254
N: 129637

PROJECT MGR	DESIGNED BY	DRAWN BY	CHECKED BY	SCALE	DATE	PROJECT NO	FIGURE
RDT	–	HLB/MG	TMO	NONE	OCT 94	60378.90	

DRAWING NAME: :\HORIZONS\NEW\OU11\WELLS\MW941129
DATE:09/07/1995 TIME:09:28

EA ENGINEERING AT ELLSWORTH AFB
WELL DEVELOPMENT RECORD

Well Designation MW941129 Development Technician Jim Johnson
Date Grouted 8-18-94
Date Development Started 8/21/94 Date development concluded 8/21/94
Length of Sandpack 12 ft
Depth of Well 27.19
Depth to Water 20.15 Depth to NAPL ______
Liquid Depth 7.04 x 0.16 = 1.1 (vol. of water in 2" PVC)
Liquid Depth 7.04 x 4.07 = 28.7 (vol. of water in 10" borehole)[1]
Vol. of water in 10" borehole (28.7)- vol. of water in 2" PVC (1.1) = 27.6 (vol. of annular space)
= 28
Vol. of annular space (28)x 0.30 = (8.4) (vol. of water held in sandpack)
Vol. of water in sandpack (8.4) + vol. of water in 2" PVC (1.1) = (9.5) (one well volume)

WELL VOLUME	GAL	TIME	pH	CONDUCTIVITY uMHOS	TEMP C	TURBIDITY NTU
INITIAL	0	9:02	8.16	1350	16.9	>1000
1	9.5	9:44	7.70	1500	14.2	>1000
2	19	10:31	7.91	1590	14.4	>1000
3	28.5	10:59	8.10	1550	14.1	> 1000
4	38	11:26	7.97	1550	14.5	>1000
5	47.5	12:55	7.87	1900	24.8	42.9
6	57	14:03	7.34	1900	25.1	36.2
7	66.5	14:50	7.65	1850	23.0	24.7
8	76	15:42	7.66	1900	25.8	4.96
9	85.5	16:28	7.57	1900	24.9	4.92
10	95	17:12	7.56	1975	24.6	4.79
11	104.5	18:00	7.52	1900	24.0	4.25

Total number of gallons removed 105 Average pumping rate 0.076 gal/min approx.
Equipment used Bailer & G. Pump Number of drums generated 2
Comments: Began surge at 9:00. Ended surge at 11:00.
(G. Pumped) from 11:20 to 18:00
Final depth to water = 20.18 ft

[1] If the height of the sandpack is greater than the liquid depth, use the height of the sandpack to determine the vol. of the 10" borehole.

ELLSWORTH AFB, SOUTH DAKOTA RI 1994

WELL GAUGING, PURGING AND SAMPLING SHEET

WELL INFORMATION

Well No.: MW941129
Date: 9/5/94
Gauger: J. Smith
Time: 0940
Well Diameter: 2
Sounding Method: W.L.I.
Stickup or ~~Flush~~
Measurement Ref.: T.O.C.

GAUGING AND PURGING

Well Depth: 28.16
Purge Method: 2" sub Grundfos
Depth to Liquid:
Purge Rate: < 1/2 gpm
Depth to Water: 20.07
Purge Time:
Liquid Column: 8.09
Purge Volume:
32.93 − 1.29 = 31.64
9.49 + 1.29 = 10.78
Liquid Volume: 10.78
Pump Dry? Describe:

SAMPLING INFORMATION

Sampler: J. Smith
Date: 9/5/94
Time: 1500
Split? SMS ~~No~~ Yes
With Whom? — MRD LABS
Type of Sampling Equipment: Peristaltic
Sample Analyte: TPH | TCL VOA | TCL SVOCS | TCL Pest/PCB | Metals Total/Dissolved | Others
DUP 3 & MRD 3 performed. (MW9411MRD3 & MW9411DUP3
P. Glycol
B. Carbitol

WATER QUALITY

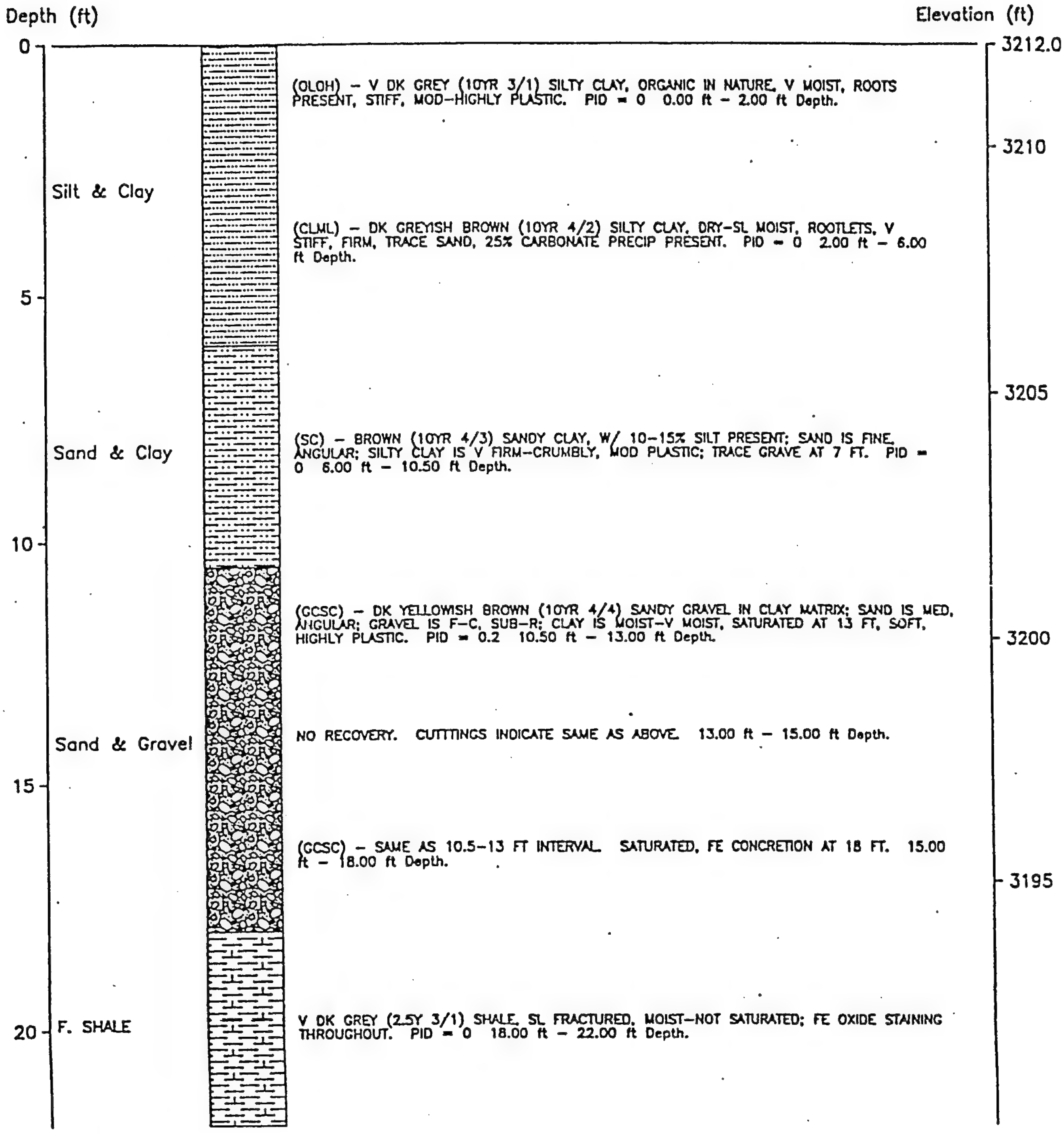
WELL VOLUME	GAL	TIME	pH	CONDUCTIVITY uMHOS	TEMP C	TURBIDITY NTU
Start 0945 INITIAL	2	0950	6.82	1600	14.4	>>1000
1	11	1013	7.09	1500	14.1	22.0
2	22	1037	7.10	1500	14.6	10.3
3	33	1105	6.99	1505	14.7	7.35
4	44	1131	7.06	1510	14.8	8.12
5 (1)	55	1155	7.01	1510	14.8	4.87
(2)		1400				
5.5	60	1418	7.23	1520	14.7	5.69
		1428				4.35
SAMPLE						

DO = 6.13

(1) Grundfos purging complete (2) Begin peristaltic purging.

SOIL BORING NO: SB9411120 (MW 941148)

SOIL BORING LITHOLOGY DIAGRAM



Boring Completion Date

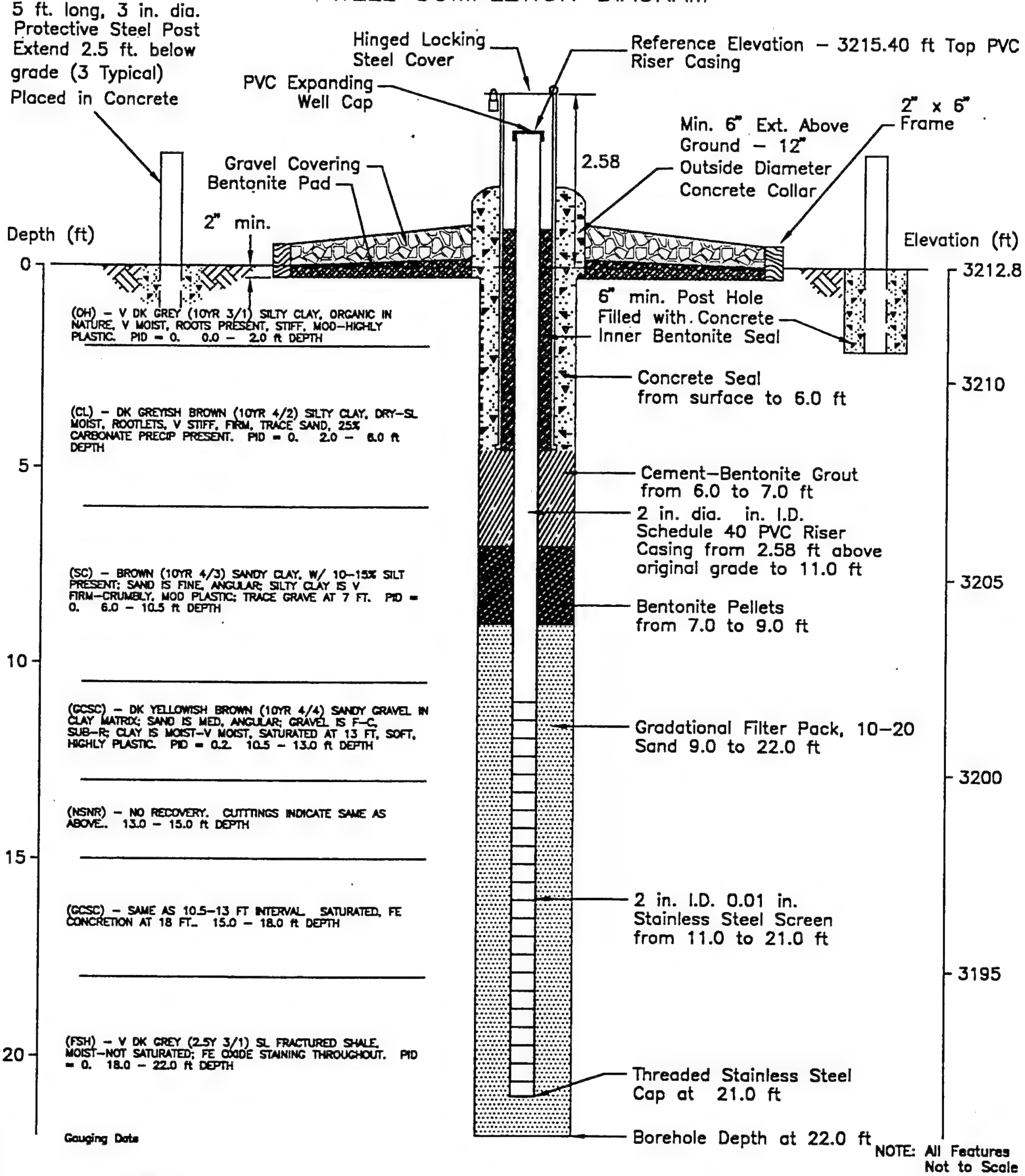
ELLSWORTH AIR FORCE BASE

Coordinates E: 1164067.05
N: 133963.08

PROJECT MGR	DESIGNED BY	DRAWN BY	CHECKED BY	SCALE	DATE	PROJECT NO	FIGURE
RT	HLB	TRB/MG	HLB	NONE	APR/95	60378.90	

WELL NO: MW941148 [SB9411120]

WELL COMPLETION DIAGRAM



ELLSWORTH AIR FORCE BASE

Coordinates E: 1164067
N: 133963

PROJECT MGR	DESIGNED BY	DRAWN BY	CHECKED BY	SCALE	DATE	PROJECT NO	FIGURE
RDT	–	HLB/MG	TMO	NONE	OCT 94	60378.90	

DRAWING NA... :\HORIZONS\NEW\OU11\WELLS\MW941148
DATE:09/07/1995 TIME:11:34

EA ENGINEERING AT ELLSWORTH AFB
WELL DEVELOPMENT RECORD

Well Designation MW941148 Development Technician B. Schulz / T. Kuxhaus

Date Grouted 12/03/94

Date Development Started 12/22/94 Date development concluded 12/23/94

Length of Sandpack 12.0'

Depth of Well 22.0'

Depth to Water 13.97 Depth to NAPL ______

Liquid Depth 8.03 x 0.16 = 1.28 (vol. of water in 2" PVC)

Liquid Depth 8.03 x 4.07 = 32.68 (vol. of water in 10" borehole)[1]

Vol. of water in 10" borehole (32.68) - vol. of water in 2" PVC (1.28) = 31.40 (vol. of annular space)

Vol. of annular space (31.40) x 0.30 = (9.42) (vol. of water held in sandpack)

Vol. of water in sandpack (9.42) + vol. of water in 2" PVC (1.28) = (10.70) (one well volume)

WELL VOLUME	GAL	TIME	pH	CONDUCTIVITY uMHOS	TEMP C	TURBIDITY NTU
INITIAL	60	1015	6.21	1050	25.0	1000
Sample #1	10.7	1030	6.65	950	25.0	30.6
Sample #2	10.7	1045	6.52	950	25.0	2.66
Sample #3	10.7	1100	7.59	980	25.0	4.13
Sample #4	10.7	1115	7.57	980	25.0	1.8
Sample #5	10.7	1128	7.61	1000	25.0	1.3
Sample #6	10.7	1142	7.55	975	25.0	0.71

Total number of gallons removed 64.2 Average pumping rate 0.89 gpm

Equipment used Grundfos Pump, PH, Conductivity + Turbidity Meters Number of drums generated 3

Comments: PH Cal - Slope 97.3

Grundfos Pump Rate = 100

Note: Suspect Temp of 25.0 C (Measured w PH meter) in error. Measured Temp of 14.0 ± .2° C with Conductivity meter

[1] If the height of the sandpack is greater than the liquid depth, use the height of the sandpack to determine the vol. of the 10" borehole

ELLSWORTH AFB, SOUTH DAKOTA RI 1994

WELL GAUGING, PURGING AND SAMPLING SHEET

WELL INFORMATION

Well No.: MW94-1148   Date: 1/19/95

Gauger: J. Smith   Time: 1115

Well Diameter: 2"   Sounding Method: W.L.I.

Stickup or Flush   Measurement Ref.: T.O.C.

GAUGING AND PURGING

Well Depth: 23.64   Purge Method: Peristaltic

Depth to Liquid: Purge Rate: <1 gpm

Depth to Water: 14.16   Purge Time:

Liquid Column: 9.48   Purge Volume:

Liquid Volume: 12.64

(9.48)(0.16) = 1.52
(9.48)(4.07) = 38.58
38.58 - 1.52 = 37.06
(37.06)(0.30) = 11.12
11.12 + 1.52 = 12.64

Pump Dry? Describe: -

SAMPLING INFORMATION

Sampler: J. Smith   Date: 1/19/95   Time: 1400

Split? No   With Whom? —

Type of Sampling Equipment:

Sample Analyte: TPH | TCL VOA | TCL SVOCs | TCL Pest/PCB | Metals Total/Dissolved | Others

WATER QUALITY

	GAL	PH	TURBIDITY	CONDUCTIVITY	DISSOLVED OXYGEN	TEMP
Initial:	2	8.05	>>1000	1020	–	11.3
Vol-1:	13	7.83	4.5	950	–	11.2
Vol-2:	26	7.82	0.7	950	–	11.5
Vol-3:	39	7.81	0.5	950	9.50	10.9
@ Sample:		7.81	0.5	950	9.50	10.9

COMMENTS (Well condition, Weather, etc):

Good, locked   Partly cloudy 40°F

APPENDIX B

Microseeps Analytical Method AM4.02

ANALYTICAL METHOD

AM4.02

ANALYSIS OF VOLATILE ORGANIC COMPOUNDS IN SOIL GAS

MICROSEEPS

University of Pittsburgh Applied Research Center
220 William Pitt Way
Pittsburgh, PA 15238
(412) 826-5245

ANALYTICAL METHOD AM4.02

ANALYSIS OF VOLATILE ORGANIC COMPOUNDS IN SOIL GAS

1.0 Scope and Application

1.1 Method AM4.02 is used to determine the concentration of volatile organic compounds in soil gas samples. Specifically, Method AM4.02 may be used to detect the following compounds:

pentane	benzene
hexane	toluene
heptane	m & p-xylene
octane	o-xylene
nonane	ethyl benzene
decane	freon 113
chloromethane	bromomethane
vinyl chloride	chloroethane
1,1-dichloroethylene	fluorotrichloromethane
methylene chloride	1,2-dichloropropane
1,1-dichloroethane	bromodichloromethane
1,2-dichloroethane	cis 1,3-dichloropropylene
trans 1,2-dichloroethylene	trans 1,3-dichloropropylene
chloroform	1,1,2-trichloroethane
1,1,1-trichloroethane	chlorodibromomethane
carbon tetrachloride	chlorobenzene
trichloroethylene	bromoform
tetrachloroethylene	1,2-dichlorobenzene
1,1,2,2-tetrachloroethane	1,4-dichlorobenzene
1,3-dichlorobenzene	acetone
methyl t-butyl ether	2-butanone
undecane	dodecane
tridecane	tetradecane
pentadecane	hexadecane
heptadecane	octadecane

1.2 This method is recommended for use by, or under the supervision of, analysts experienced in the operation of a gas chromatograph and in the interpretation of a chromatogram.

2.0 Summary of Method

The volatile organic compounds are analyzed using a Hewlett Packard Model 5890A Gas Chromatograph in conjunction with a Tekmar Model 7000 Automated Headspace Sampler and an H.P. 3396A Networking Integrator. A Supelco, 60M x 0.75mm i.d. Vocol, wide bore capillary column is used in conjunction with an output splitter connected to an electron capture detector and a flame ionization detector. The integrator is interfaced to a microcomputer for data storage and processing. Data transfer and analyses are facilitated using a chromatography data system (Chrom Perfect, Justice Innovations).

3.0 Interferences

3.1 Contamination by carryover can occur whenever high-level and low-level samples are sequentially analyzed. The Tekmar 7000 provides continuous flushing of the sample loop and sample valve while in the standby mode between analyses. This flush flow should be maintained and the sample valve and loop should be kept heated.

3.2 The analyst should demonstrate the absence of carryover contamination by analysis of the contents of the sample loop when purged with pure nitrogen. This demonstration should be performed prior to the analysis of a sample set and when carryover contamination is suspected (after high samples). In the event that 'ghost peaks' (peaks similar to previous sample) appear when a pure nitrogen sample is analyzed measures should be taken to eliminate the carryover contamination.

3.3 Extra peaks in a chromatogram can be actual peaks from a previous run. Contamination from late eluting peaks can occur when injection to injection time is too short or when the column conditioning program described in section 3.4 is not adequate. The HP 5890A is equipped with a temperature programmable oven which can be utilized to minimize this interference.

3.4 The analyst should be certain that all compounds have eluted from the previous analysis prior to analyzing any sample or standard. This can be accomplished by elevating the oven temperature after an analysis until such time that a clean stable baseline is obtained. If samples or standard chromatograms contain suspected 'extra peaks' the sample should be reanalyzed after a clean baseline is established.

3.5 Other interferences that affect the sample analysis can come from sample vials, vial septums, needles and equipment used to collect the sample. Before and during sample analysis, sample blanks (evacuated vials filled with high purity nitrogen, and sample vials from the field filled with ambient air) should be analyzed to assure the absence of interferences.

4.0 Materials and Equipment

4.1 Sample vials: 22 ml glass vials (Hewlett Packard #9301-0716 or equivalent). Vials should be free of all interfering compounds prior to use. This can be accomplished by washing and rinsing with hydrocarbon free water followed by heating to 100 degrees C for 1 hour followed by purging with pure nitrogen.

4.2 Septums: Teflon lined septums (Wheaton #224168 or equivalent) may be used.

4.3 Gas Chromatograph: The Hewlett Packard 5890A Gas Chromatograph is equipped with a Supelco, 60M x 0.75mm i.d. Vocol, wide bore capillary column connected to an electron capture detector and flame ionization detector.

4.4 Headspace Sampler: A Tekmar (Model 7000) equipped with a Tekmar (Model 7050) automated carrousel is used. The carrousel contains 50 slots for headspace vials. The vials are automatically transferred from the carrousel to a platen where they are heated for a preset time prior to injection. The headspace sampler also contains a heated sample valve, heated sample loop and heated transfer line to facilitate transfer of the sample onto the column in the gas chromatograph.

4.5 Data Collection: The output of the chromatograph is directed to a Hewlett Packard (HP-3396A) Networking Integrator which passes the data to a personal computer for data processing with Chrom Perfect software.

5.0 Sample Preparation and Analysis

5.1 Sample vial preparation: All sample vials should meet specifications as noted in sections 4.1 and 4.2 above. Vials should be tightly capped and evacuated to a pressure of less than 100 millitorr. The vial septum should be punctured only with needles of 22 gauge or smaller.

5.2 The evacuated sample vials should be filled with sample or standard gas to a positive gauge pressure. Sample vials should be used (filled with sample) within two weeks of preparation.

5.3 Place the 22 cc sample vials directly into the Tekmar 7050 carrousel and program the headspace autosample as described in section 8.2.

5.4 The headspace sampling unit will preheat the vial, mechanically puncture the septum, transfer the sample to the heated sample loop, then inject the sample into the column flow stream via a heated transfer line.

6.0 Standards and Calibrations

6.1 Gas standards or liquid standards may by used to achieve calibrations. In some situations it may be necessary to use both types of standards. Certified commercial gas standards are most desirable, but may not always be available for all the compounds or for the concentration levels of the compounds of interest.

6.2 Commercial gas standards are introduced by filling an evacuated 22ml headspace vial with standard gas. The gas standards are placed in the vials and analyzed in the same manner as samples (as described in section 5.0). The concentrations used are those certified by the manufacturer.

6.3 Liquid standard solutions are injected directly into a

capped vial and allowed to vaporize. These standards may be produced from high purity compounds as described in Standard Preparation Method SP3 or from commercially available blends in methanol. The liquid standard solutions are placed in vials that meet specifications described in sections 4.1 and 4.2. The vials used must be capped and be at atmospheric pressure when the liquid standard is injected. The standard vial is then analyzed in the same manner as a sample vial as described in section 5.3.

6.4 At the beginning of a project or sample set, standards of appropriate calibration ranges will be run at least two times or until the results agree with a percent standard deviation no greater than 10%.

6.5 Calibration tables should be set up using an external standard method with the Chrom Perfect data system. It is recommended that the calibration table for individual compounds contain at least three standard concentration levels.

6.6 During the course of analyzing samples at least one standard should be run for every 10 samples.

6.7 The instrument response (for any one subsequent standard in section 6.5 above) must not vary by more than 25% from the mean of the initial calibration.

7.0 <u>Quality Control</u>

7.01 If the parameters set forth in section 6.6 are not met the analytical program will be terminated until the cause is determined and a solution is effected.

7.02 Before and during sample analysis, instrument blanks (sample loops filled with flush nitrogen) should be analyzed to assure the absence of interferences as described in section 3.0 above.

7.03 Before and during sample analysis, sample blanks (evacuated vials filled with high purity nitrogen, and sample vials from the field filled with ambient air) should be analyzed to assure the absence of interferences.

7.04 Prior to the analysis of a sample set, multiple standards, at different concentration levels, should be analyzed to establish an initial calibration table. During sample analysis, standards should be run at a rate of 1 for each 10 samples.

7.05 Standards analyzed during the course of analyzing samples are used to monitor individual compound calibration and peak retention time stability. All chromatograms should be examined

by an experienced analyst.

7.06 The soil gas sample vial is pressurized at the time of sampling. This pressure preserves sample integrity since any leakage is out of the vial and does not result in contamination or sample dilution.

7.07 Throughout the analysis the headspace gas is injected mechanically from a sample loop to achieve a uniform sample size. The flow through the sample loop comes directly from the sample vial which has been pressurized.

7.08 The headspace sampling unit contains a heated platen as well as a heated sampling loop and transfer line. The latter two zones are continually flushed with nitrogen between sample analyses to minimize the chance of instrumental carry over. This nitrogen in the sample loop is injected periodically to check for instrument contamination.

7.09 Once the headspace vials are punctured in the headspace unit, the sample loop is allowed to equilibrate to atmospheric pressure just prior to injection. This insures that an accurate, equal volume will be injected each time. Each vial is analyzed one time only.

7.10 Calibration records are generated and stored in the computer. All such records will be maintained in the laboratory during the course of the project.

8.0 Instrument Conditions

8.1 Gas Chromatograph:

Injection Temp. 220 deg. C.
Flame Ionization Detector Temp. 220 deg. C.
Electron Capture Detector Temp. 375 deg. C.
Oven Temp. Program:

- Initial temp. 35 deg. C.
- Hold 10 min.
- Rate 4 deg. min. to 135 deg. C.
- Hold .01 min.
- Rate 6 deg. min. to 219 deg. C.
- Hold 15 min.

Equilibration Time 1 min.
Initial E.C.D. Signal Range 5
Initial F.I.D. Signal Range 4
Carrier Flow Rates: (output of column split)

- Head Space Sampler in 12 cc/min.
- Make up gas to E.C.D. 76 cc/min.
- Make up gas to F.I.D. 34 cc/min.
- Total column 12 cc/min.

Hydrogen Pressure 22 psig.
Flame Air Pressure 30 psig.

8.2 Headspace Sampler:

Platen Temp. 75 deg. C.
Valve/Loop Temp. 110 deg. C.
Transfer Line 110 deg. C.
Sample Equilibration time 45 min.
Sampling interval 75 min (remote)
Valve Timing:

- Pressurize 0.0 min.
- Vent/fill loop 0.25 min.
- Loop equilibration 0.33 min.
- Inject to G.C. 1.0 min.

Carrier Flow 12 cc/min.

APPENDIX C

Direct Push Investigation and EPA Comments

Jop

TECHNICAL MEMORANDUM

Date: November 6, 1995

To: KellieAnn Kacheck

From: Keith Anderson and Jeff Groen

Subject: Summary and Recommendations for Further Characterization of TCE Contamination at BG-04, Ellsworth AFB, South Dakota

Rust conducted a direct push (DP) investigation at site BG-04 during the period from June 2 to 8 and September 19 to 28, 1995. The purpose of the investigation was to further characterize the extent and magnitude of trichloroethylene (TCE) in the ground water in the vicinity of monitoring well MW941148, where previous investigations had revealed a concentration of 23.0 ug/L.

The June investigation did not delineate the TCE contamination. Two memorandums, dated July 20 and August 30, 1995, were written and submitted to you, which summarized the results of the June investigation. The purpose of this memorandum is to summarize the results of both the June and September investigations as well as present recommendations for further work. Attached Figures 1 and 2 show the BG-04 study area, all attempted DP borings and depths, and ground water analytical results. Table 1 shows mobile laboratory analytical results, DP boring depths, and fixed-base QC laboratory analytical results.

SUMMARY OF FIELD INVESTIGATION

- Sixty-three different locations were investigated via DP methods. The depth of the DP borings ranged from 1 to 32.5 feet.

- Ground water samples were collected from 31 of the 63 locations. Thirty-two of the 63 locations did not produce water over a period of 1 to 2 days.

- Two water wells on private property were sampled, and two surface water samples were collected from the private property pond.

- All ground water samples were analyzed on-site for trichloroethylene (TCE). Several samples were also analyzed for total 1,2 dichloroethylene (DCE), vinyl chloride, and other volatile organic compounds.

- Analytical results from 13 DP locations indicated TCE concentrations over the South Dakota Human Health Standard (HHS) of 5.0 ug/L. The highest mobile laboratory concentration of TCE from the DP locations was 1067.9 ug/L (sample GP951148-ELN220-25') immediately north of water well ELN200 and south of the private property pond.

- No significant concentrations of TCE were observed at the DP locations south of MW941148, but the western, northern, and eastern reaches of the DP investigation (GP951148WJ, GP951148N5, and GP95EXS380) were contaminated at levels of 117.1, 43.1, and 4.7 ug/L, respectively, based on mobile laboratory analytical results. All TCE analytical results are shown on Table 1 and Figure 2.

- A water sample collected from monitoring well, MW941148, demonstrated a TCE concentration of 20.0 ug/L, based on fixed-base analytical results.

- Water well, WW95ELN200, appears to be an out-of-use livestock/irrigation well, which Mr. Ed Pain indicated was set at a depth of 20 to 25 feet. A water sample collected from a hand-bailer demonstrated TCE concentrations of 113.9 ug/L by the mobile laboratory and 22 ug/L by the fixed-base QC laboratory. The TCE concentrations did not correlate well between laboratories. This well was not purged prior to sampling.

- Another approximately 3-foot diameter water well (WW95EXS380) was sampled with a hand-bailer. Mobile laboratory analysis of the sample demonstrated TCE concentrations of 356.8 ug/L; the fixed-base QC laboratory detected TCE concentrations of 17 ug/L. This well was not purged prior to sampling.

- Two surface water samples were collected along the northwest and southeast edges of a private property pond, located east of the base boundary. No detectable concentration of TCE (< 0.2 ug/L) was reported by the mobile laboratory for either water sample.

Ground water flow is presumed to be toward the east-southeast, based on a ground water contour map developed for the Final Corrective Action Plan, dated August, 1995.

The TCE contamination observed during the DP investigation does not appear to conform to the TCE isopleth map prepared by EA Engineering during September, 1995, for the OU-11 RI report. Moreover, the TCE contamination is relatively widespread (1750 feet separate the base's monitoring well and the northern-most DP location and 1750 feet separate the western-most and eastern-most DP locations), with levels above the HHS on base property and east of the property line. Although high TCE concentrations have been detected in both private property water wells, neither appears to be currently used.

RECOMMENDATIONS

This investigation has revealed varying concentrations of TCE over a relatively large area of land. No clear contaminant plume has been observed; instead, high concentrations are separated by much lower concentrations or the absence of a water sample. The site's geology may be responsible for the significant TCE variations, and more TCE contamination exists in the study area than was previously supposed.

At any given location, the ground water flow within the unconfined aquifer may vary. The flow direction and gradient needs to be determined by actual ground water measurements and determinations of the paleotopography of the underlying Pierre Shale surface. Paleotopographic highs in the Pierre Shale will create "gaps" in mapping the concentration of TCE or reduce the concentration, due to changes in the aquifer thickness and hydraulics. Consequently, we recommend that the depth to shale bedrock be mapped along the north-south and east-west transects from monitoring well MW941148. Such a shale profile would be completed via a shallow seismic refraction survey. See the enclosed sheet for the method's standard operating procedure and Figure 3 for a schematic of the seismic refraction operation.

The survey will be performed to determine the depth and elevation of the bedrock surface and identify possible alluvium-filled channels in the bedrock surface that may provide preferential ground water flow pathways. The seismic refraction survey will be conducted along two transects, consisting of one 3,000 foot north-south transect and a 1,500 foot east-west transect. See Figure 2 for the proposed transect locations. The survey will be conducted using a BISON single channel 1570C seismograph. One seismic line includes ten soundings spanning approximately 100 feet. Three additional points may be added per line depending on field data analysis. We propose to determine the shale profile by completing one seismic line every 150 feet. The maximum depth of investigation will be approximately 40 feet. The end points of the seismic lines will be staked and surveyed. Stakes will also be surveyed along each line at 150 foot intervals in order to tie results of the seismic survey to location in the field. In addition to determining the shale profile, stratigraphic characteristics of the alluvial material will also be evaluated. A total of 30 seismic lines are proposed along the two transects. An additional 10 seismic lines will be completed at locations to be determined in the field. These additional lines will allow for fence diagrams of the shale paleotopography beyond the two transects.

Only one soil boring log is available for the study area, SB9411120; this soil boring was converted to monitoring well MW941148. The boring log is enclosed with this memorandum. After completing the seismic survey, we recommend that six to eight soil borings be advanced in the shale's paleotopographic troughs to better characterize subsurface geology. Monitoring wells will be

installed after completing the soil borings. These wells will be used to characterize the unconfined aquifer in this vicinity and quantify the TCE contamination.

We also recommend an historical aerial photograph assessment of the area. Some photographs will be enlarged to better determine recent activities on the base (housing development activities, circa 1990), and possible refuse dumping east of the base property.

In brief, we recommend that the following:

- Shale's paleotopography be determined via shallow seismic refraction techniques
- Better geological characterization of area via soil borings
- Better ground water and TCE characterization via monitoring well sampling and analysis
- Better assessment of on-base and off-base activities via aerial photograph interpretation

In addition, the northern and western extent of TCE contamination has not been determined. At least two of the proposed monitoring wells will be located beyond the current study area in order to better define the TCE extent in these directions.

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Table 1
Identification of DP Location and Laboratory Results
BG-04 Investigation, Ellsworth AFB
November 1, 1995

DP Identification Based on Figure 2		Improper DP Identification Geoprobe Team		Improper DP Identification By Surveyors		Depth of DP EOB (ft)	Date Collected	Mobile Lab Results[1] (µg/L) TCE	Mobile Lab Results[1] (µg/L) DCE	Fixed-Base Results[1] (µg/L) TCE	Fixed-Base Results[1] (µg/L) DCE	Fixed-Base Results[1] (µg/L) Vinyl Choride
Water Well	WWELN200						9-21-95	113.9	-[3]	22	<3.0	<1.0
Water Well	WWEXS380						9-24-95	356.8	-	17	-	-
MW941148[2]							6-15-95	-	-	20	10.0	<10
Pond	NW											
Pond	SE											
GP951148	EB					25	9-21-95	1.9	-	-	-	-
GP951148	ED					25	9-21-95	0.7	-	-	-	-
GP951148	EF					20	9-21-95	1.6	-	-	-	-
GP951148	EH					25	9-21-95	1.1	-	-	-	-
GP951148	EJ					25	9-21-95	6.7	-	-	-	-
GP951148	EL					25	9-24-95	0.2	-	-	-	-
GP951148	ELN200					6.5		-	-	-	-	-
GP951148	ELN220					21	9-28-95	1067.9	-	-	-	-
GP951148	EN					9/11[3]		-	-	-	-	-
GP951148	EP					6/10		-	-	-	-	-
GP951148	ER					4/11		-	-	-	-	-
GP951148	ERN200					7		-	-	-	-	-
GP951148	ERN400					8		-	-	-	-	-
GP951148	ERS200					6.5		-	-	-	-	-
GP951148	ERS400					17	9-24-95	2.4	-	3.8	<3.0	<1.0
GP951148	ERS600					25	9-24-95	<0.2	-	-	-	-
GP951148	EXS380	GP951148	EZ			14.5	9-24-95	4.7	-	-	-	-
GP951148	4' E. of MW					25	6-08-95	21.5	<1.0	-	-	-
GP951148	NB	GP951148	NA	GP951148	NA	15	6-04-95	0.78	<1.0	-	-	-
GP951148	ND	GP951148	NB	GP951148	NB	15	6-04-95	3.69	5.53	-	-	-
GP951148	NF	GP951148	NC			15/12		-	-	-	-	-
GP951148	NG					18		-	-	-	-	-
GP951148	NH	GP951148	ND			15/9		-	-	-	-	-
GP951148	NI					25	9-24-95	226.7	-	-	-	-
GP951148	NJ					13		-	-	-	-	-
GP951148	NL					27	6-08-95	17.8	<1.0	-	-	-
GP951148	NN					15		-	-	-	-	-
GP951148	NO					20	9-24-95	214.9	-	-	-	-
GP951148	NQ					17	6-08-95	22.3	<1.0	-	-	-
GP951148	NQE100					11	9-21-95	1.5	-	1.9	<3.0	<1.0
GP951148	NQE200					13		-	-	-	-	-
GP951148	NQE300					12/14		-	-	-	-	-
GP951148	NQE400					7/13		-	-	-	-	-
GP951148	NQE700					12		-	-	-	-	-
GP951148	NQE800					30	9-24-95	5.7	-	-	-	-
GP951148	NQE900					27	9-24-95	<0.2	-	-	-	-
GP951148	NS					15	9-24-95	149.0	-	-	-	-
GP951148	NU					2/2/9		-	-	-	-	-
GP951148	NUE20					1/1.5/15	9-28-95	4.6	-	-	-	-
GP951148	NW					12/5/12		-	-	-	-	-
GP951148	NWE20					1/3/4		-	-	-	-	-
GP951148	NY					15/11		-	-	-	-	-
GP951148	N1					28		-	-	-	-	-
GP951148	N1E20					18		-	-	-	-	-
GP951148	N3					1/7		-	-	-	-	-
GP951148	N5					29	9-28-95	43.1	-	-	-	-
GP951148	WB	GP951148	WA	GP951148	WA	18	6-04-95	4.48	<1.0	-	-	-
GP951148	WD	GP951148	WB			22/28	6-06-95	-/2.5	-/<1.0	13	<10.0	<10
GP951148	WF	GP951148	WC			22/30	6-06-95	-/2.5	-/<1.0	-	-	-
GP951148	WH	GP951148	WD			22/30	6-08-95	-/7.7	-/<1.0	-	-	-
GP951148	WJ					32.5	9-24-95	117.1	-	-	-	-
GP951148	SB	GP951148	SA	GP951148	SA	15		-		-	-	-
GP951148	SC					11[1]		-		-	-	-
GP951148	SD	GP951148	SB			16		-		-	-	-
GP951148	SF	GP951148	SC			21	6-04-95	0.1	<1.0	-	-	-
GP951148	SH	GP951148	SD			26	6-04-95	0.17	1.35	-	-	-
GP951148	SJ					29	6-06-95	1.5	<1.0	1.2	<10.0	<10
GP951148	SM					28		-	-	-	-	-
GP951148	SO					31.5		-	-	-	-	-
GP951148	SPE20					19		-	-	-	-	-
GP951148	SS					23		-	-	-	-	-
GP951148	ST					27		-	-	-	-	-
GP951148	SWE20					26		-	-	-	-	-

[1] DP borings and mobile laboratory analyses by Global Environmental in Rapid City, SD QC water samples analyzed by Quanterra Laboratories in Arvada, CO.
[2] Water sample collected from wells via hand-bailing. (All other water samples collected via DP methods
[3] Indicates that no sample was collected for analysis of the selected parameter. 15/12 indicates multiple attempts to collect ground water at the same location.

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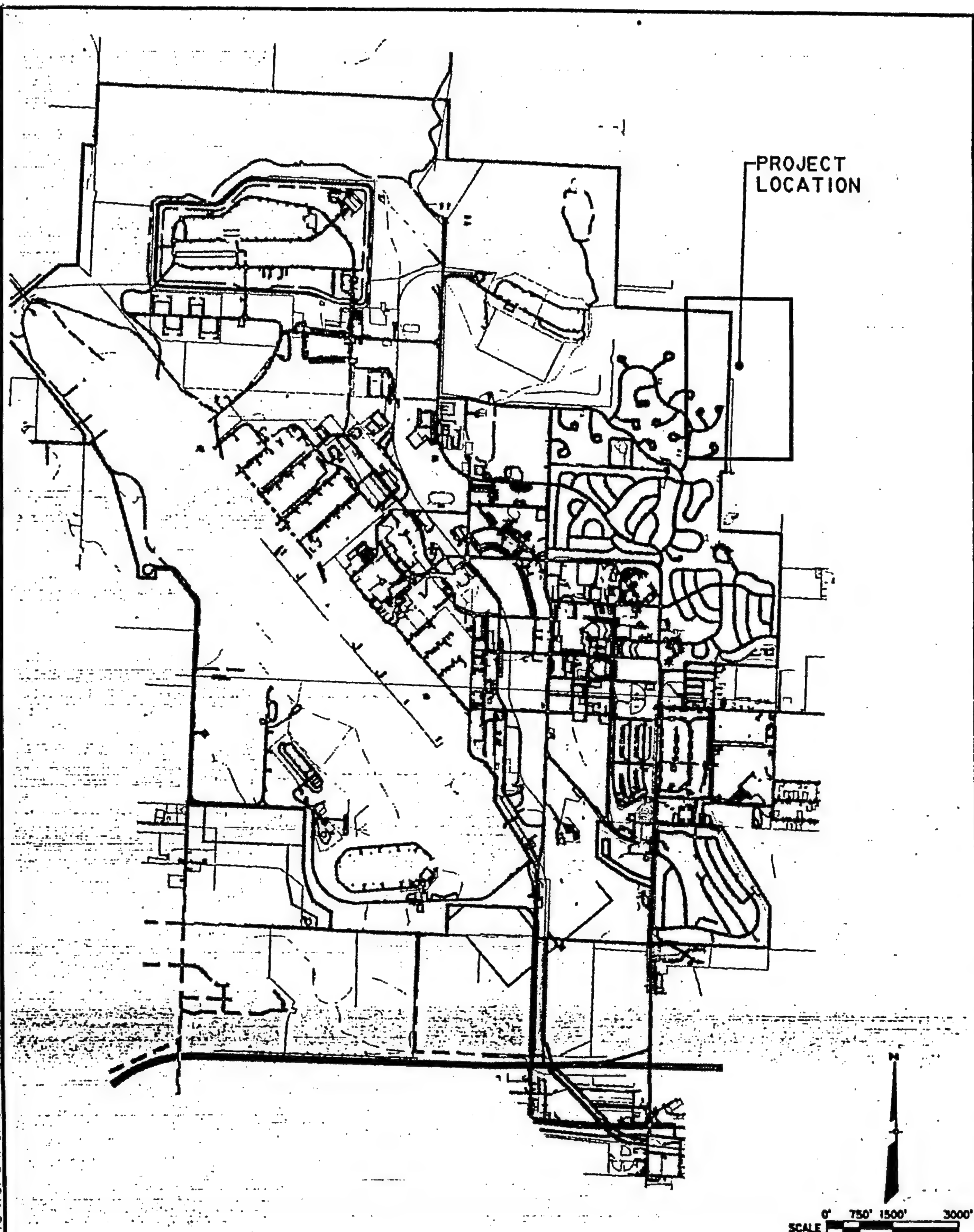
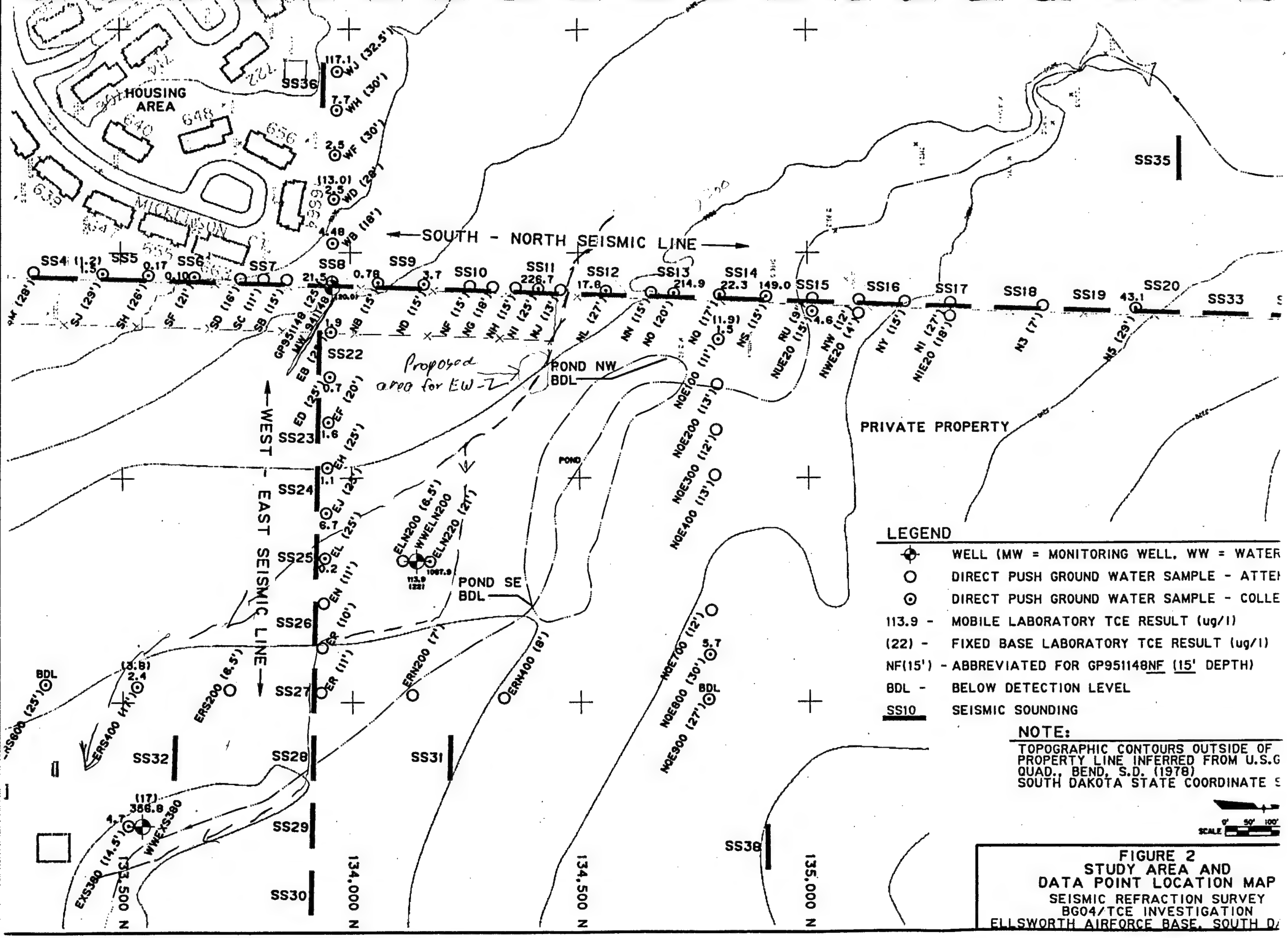


FIGURE 1
PROJECT LOCATION PLAN

ELLSWORTH AFB, SOUTH DAKOTA
PREPARED FOR U.S. ARMY CORPS OF ENGINEERS



LEGEND

- WELL (MW = MONITORING WELL, WW = WATER
- ○ DIRECT PUSH GROUND WATER SAMPLE - ATTE
- ⊙ DIRECT PUSH GROUND WATER SAMPLE - COLLE
- 113.9 - MOBILE LABORATORY TCE RESULT (ug/l)
- (22) - FIXED BASE LABORATORY TCE RESULT (ug/l)
- NF(15') - ABBREVIATED FOR GP951148NF (15' DEPTH)
- BDL - BELOW DETECTION LEVEL
- SS10 - SEISMIC SOUNDING

NOTE:
TOPOGRAPHIC CONTOURS OUTSIDE OF PROPERTY LINE INFERRED FROM U.S.G QUAD., BEND, S.D. (1978)
SOUTH DAKOTA STATE COORDINATE S

FIGURE 2
STUDY AREA AND
DATA POINT LOCATION MAP
SEISMIC REFRACTION SURVEY
BG04/TCE INVESTIGATION
ELLSWORTH AIRFORCE BASE, SOUTH D

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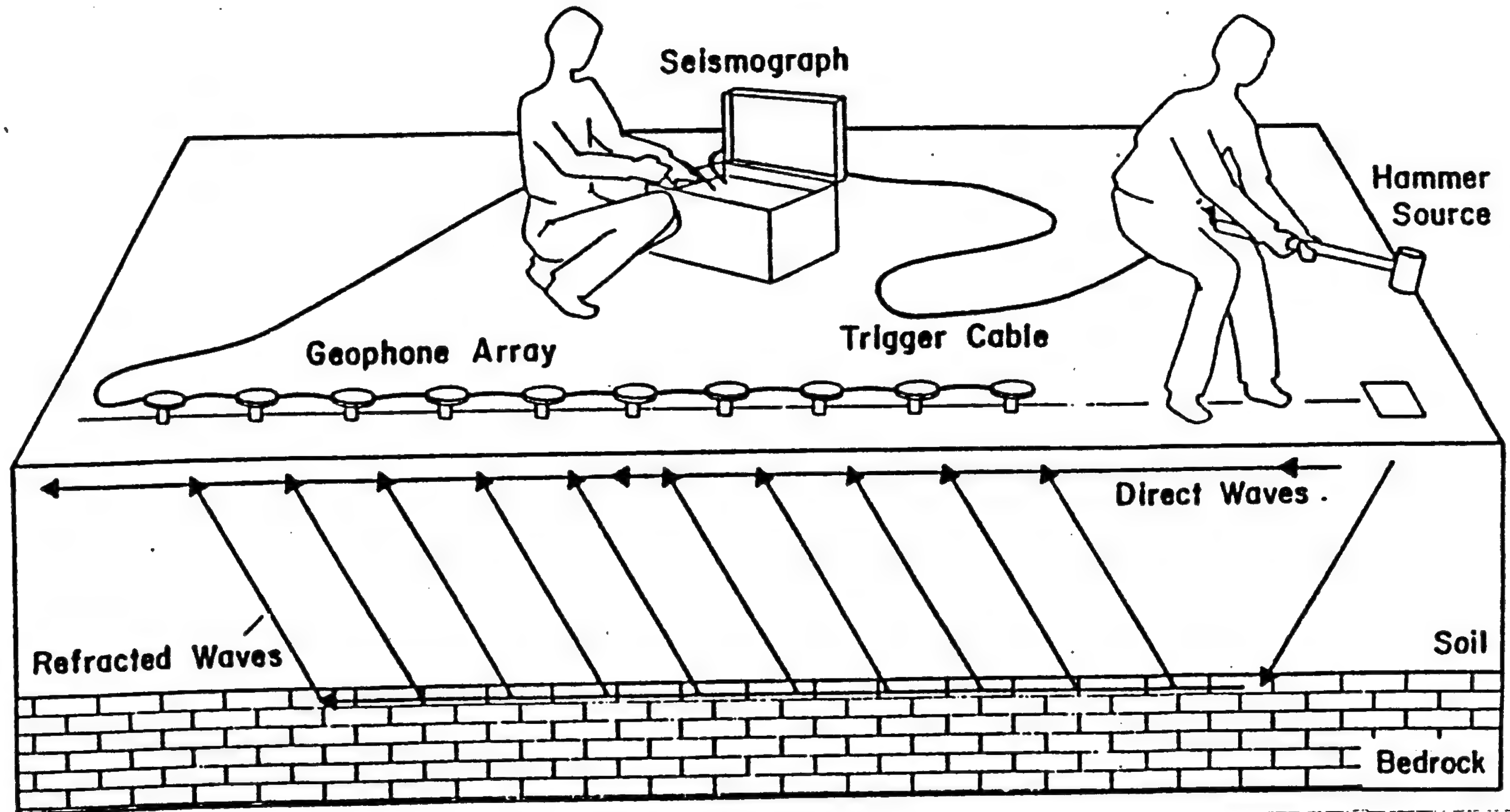

FIGURE 3
SCHEMATIC OF FIELD LAYOUT FOR
SEISMIC REFRACTION TECHNIQUE

ELLSWORTH AFB, SOUTH DAKOTA
PREPARED FOR U.S. ARMY CORPS OF ENGINEERS

STANDARD OPERATING PROCEDURE FOR SHALLOW SEISMIC REFRACTION SURVEY

Seismic refraction techniques are used to determine the thickness and depth of geologic layers based upon the velocity or travel time of seismic wave propagation within the subsurface. Seismic refraction methods can provide subsurface information regarding: depth to a well-consolidated layer, such as bedrock; dip of the bedrock surface or stratigraphic layer boundaries; and location of faults or irregularities on the bedrock surface.

In a seismic refraction survey, seismic waves, transmitted into the subsurface, travel at different velocities in different types of soil and rock and are refracted (or bent) at the interfaces between the soil and rock layers. Figure 1 demonstrates how refraction affects the path of travel. An array of geophones on the surface measures the travel time of the seismic waves from the source to the geophones. The time required for the wave to complete this path is measured, permitting a determination to be made of the number of layers, the thicknesses of the layers and their depths, as well as the seismic velocity of each layer. The wave velocity in each layer is directly related to its material properties, such as density and hardness.

The survey is conducted by one person introducing the seismic signal and another person recording the arrival time of the vibration on the seismograph. Seismic refraction data interpretation usually involves both manual and computer analysis of seismic wave travel time graphs.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION VIII
999 18th STREET - SUITE 500
DENVER, COLORADO 80202-2466

Ref: 8EPR-FF

November 30, 1995

Dell S. Peterson, PE
Installation Restoration Program Manager
28 SPTG/DEVR
Ellsworth AFB, South Dakota 57706-5000

Subject: Comments on the **Technical Memorandum** for BG-04, 6 November 1995.

Dear Mr. Peterson:

The general approach for future investigations at the BG-04 area is acceptable. Below are several comments pertaining to the work to be performed as part of the future investigations. Additional review and comment may be necessary when the specifics of the investigations will be presented.

Even though this action is part of a removal action investigation, the comments below represent some of the minimum requirements for a remedial investigation. These will help insure that the scope of any removal action will address all the risk for the geographical area to be remediated. If all the risk for a certain area is addressed during a removal action (i.e. off-Base near BG-04), a subsequent remedial action may not be necessary for that area if the removal action complies with the applicable and relevant and appropriate requirements of a remedial action. A Record of Decision for OU-11 would indicate that a removal action addressed all the associated risk for a certain area.

1. During future ground-water sampling events, purge and sample the wells according to the Basewide Field Sampling Plan. This would include purging three well volumes from the ground-water wells prior to sampling, sampling the wells with low-flow pumps, and obtaining samples with a turbidity of five NTUs as the goal.

2. Of the 31 ground-water samples taken, 29 contained TCE at least above the detection limit. At most of the 32 sample locations where ground water was not encountered during the direct push, refusal occurred at a relatively shallow depth. This indicates that ground water may still exist at these locations. Review the refusal depths to determine if ground water may exist at these locations when proposing future sampling locations.

3. The sample from the northern-most area of the investigation contained TCE. Also, the samples from locations in the eastern portion of the investigation contained relatively

high levels of TCE. Future investigations in the areas of these sample points would be necessary to determine the extent of the identified contamination.

4. The memorandum states wells will be installed to help determine the levels of ground-water contamination. Ground-water wells will need to be installed in both high contamination areas and in low contamination areas. Some of the wells could be installed during the design and construction phases of the removal action. Some of the ground-water sampling objectives include: (1) acquiring representative ground-water samples, (2) acquiring samples downgradient of the plume(s) determining any future plume movements, and (3) acquiring samples from various levels from within the plume(s) to help determine the most practical cleanup method and to determine its performance.

5. It is assumed that the extent of the ground-water remediation under the removal action would be based on the extent of contamination with the MCL for TCE being the outer limit of the cleanup. Because of this criteria, the data quality objectives and the field and laboratory QA/QC procedures used in the remedial investigation would be appropriate for this removal action. Since this is a removal action, these objectives and procedures could be streamlined based on the scope and intent of the removal action. The immediate concern is to accurately identify the outer limits of the contamination which would require remediation.

If you need clarifications on any of the comments, please contact me at (303) 312-6012.

Sincerely,

Peter Ismert
Remedial Project Manager

cc: Ron Holm, SDDENR
Kellie Kachek, USACE
Kieth Anderson, RUST

APPENDIX D

BG-04 Seismic Study

Seismic Refraction Survey
BG04/TCE Investigation
Ellsworth AFB, South Dakota

U.S. Air Force
Air Combat Command

January, 1996

Prepared for:
U.S. Army Corps of Engineers, Omaha District
Contract No. DACW45-94-D-0001
Delivery Order No. 15
Project No. FXBM 95-7015

Prepared by:
Rust Environment & Infrastructure
3033 Campus Drive
Minneapolis, MN 55441

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

1.0 INTRODUCTION AND PURPOSE

Since June, 1995, Rust has conducted two direct push (DP) investigations at site BG-04 in the northeast quadrant of Ellsworth Air Force Base, South Dakota. The purpose of the investigation was to further characterize the extent and magnitude of contamination, primarily trichloroethylene (TCE), in the ground water in the vicinity of monitoring well MW941148, where previous investigations had revealed a concentration of 23.0 μg/L. This monitoring well is located along the base's eastern boundary, and TCE contamination reportedly originates from the area west of the study area. The DP investigations indicated that there was more TCE contamination in the study area than was previously supposed (1750 feet separated the base's monitoring well and the northern-most DP location and 1750 feet separated the western-most and eastern-most DP locations).

The TCE contamination observed during the DP investigation did not conform to the TCE isopleth map prepared by EA Engineering during September, 1995, for the OU-11 RI report. The DP investigations revealed varying concentrations of TCE over a relatively large area of land . No clear contaminant plume was observed; instead, high concentrations were separated by much lower concentrations or the absence of a water sample. The site's geology, particularly the bedrock topography, was suspected as controlling the TCE variations.

At any given location, the ground water flow within the unconfined aquifer may vary. The flow direction and gradient must be determined by actual ground water measurements and determinations of the paleotopography of the underlying Pierre Shale surface. Paleotopographic highs in the Pierre Shale may have created "gaps" in mapping the concentration of TCE or reduced the concentration, due to changes in the aquifer thickness and hydraulics. Consequently, a shallow seismic refraction survey was completed to "map" the depth to shale bedrock along north-south and east-west transects from monitoring well MW941148; the bedrock surface is presented in both a cross-sectional and contoured format. **This technical memorandum presents the results of the seismic refraction survey.**

The results will be utilized in subsequent investigation activities regarding the impact of the bedrock surface on ground water and TCE contaminant movement. The results of the investigation will also be evaluated in relation to the stratigraphic and hydrogeologic characterization of the site and to optimize the locations of future borings and monitoring wells.

Ellsworth AFB is located approximately 12 miles east of Rapid City, South Dakota. The study area for the geophysical investigation is located on an approximate 150 acre site and is situated on rolling terrain comprised primarily of short grasses and open land use (see Figure 1). The extent of the study area is shown in Figure 2. The locations of seismic soundings and other data point information used in the investigation are also shown. The evaluation of the seismic is based on information acquired from the geophysical investigation conducted on December 12-16,1995.

2.0 SEISMIC REFRACTION SURVEY TECHNIQUE

Seismic refraction exploration is a method of measuring time, distance, and the velocity of seismic waves transmitted and refracted through geologic formations of varying density.

The acquisition of seismic data includes three fundamental components:

1. An acoustic source;
2. Geophone(s) [i.e. acoustic receiver(s)]; and
3. A seismograph to record the data.

The acoustic source used in this survey was a ten-pound sledge hammer with an electric impact switch. A Bison Model 1570C single channel seismograph was utilized to record the seismic data. Impacts from the hammer were made onto a metal plate and time intervals electronically measured at increasing distances from the geophone, in 10-foot offset increments. By increasing offset distances, the depth of investigation is increased.

The primary function of the seismograph is to measure the time required for a seismic wave to move from its energy source (hammered plate) through the geologic units (lithology) to the geophone, and in turn display the time interval on the seismograph. Initially, the direct seismic waves from the closer hammer stations will arrive first. As the hammer stations (offsets) move away from the geophone, refracted waves moving through deeper and denser layers will begin arriving before the direct waves. With increasing offset distances, the depth of investigation increases and time intervals of seismic motion through layers of varying density will also change. The time intervals are plotted with each corresponding offset distance.

The plotted data provide trends depicting time and distance relationships associated with the underlying lithology, which is representative of single or multi-layered subsurface conditions. These data trends usually result in straight-line segments with a slope that can be used to determine the velocity associated with the underlying formations.

Inflection points resulting from a change in slope of the line segments (in multi-layered conditions) can then be used to calculate the depth where the change to a higher velocity (denser) material occurred. Occasionally, density variations within a single layer or surface variation along its contact can decrease or increase a refracted wave resulting in some scattering of plotted data. With scattered data points indicating an overall linear trend, a velocity of the layer can then be modeled for a best fit analysis and provide the layer's representative velocity.

3.0 SEISMIC REFRACTION SURVEY PROCEDURES

The seismic refraction survey consisted of two seismic lines extending across the site in a south-north and west-east direction as indicated in Figure 2. The south-north seismic line was comprised of 22 seismic soundings, designated SS1 through SS20 and SS33-SS34. Each sounding array was 100 feet in length and spaced 50 feet apart, providing a nearly continuous profile of the subsurface. Four soundings were conducted with 120 foot arrays in areas where a greater depth of investigation appeared warranted.

The west-east cross-section was comprised of ten soundings, designated SS21 through SS30. The sounding arrays for this seismic line were 100 feet in length and spaced 50 feet apart. The first sounding (SS21) was omitted from the data base as a result of an inversion layer (dense layer overlying less dense layer) preventing model development. Historical aerial photographs of the area indicate a former construction road went through this location. The remnants of the roadbed, near the surface, are likely the cause of the inversion.

Eight additional sounding, designated SS31-SS32 and SS35-SS38, were located away from the seismic lines as shown in Figure 2. These soundings provided vicinity background depth to bedrock data. Seismic data from these soundings were also used in the development of a site-wide bedrock surface contour map. The location and orientation of each seismic sounding completed in the survey, are also provided in Figure 2.

In order to determine if underlying strata was horizontal or dipping, a reverse profile (sounding array) was conducted at each sounding location. The seismic data from the reverse profile also acted as a confirmation of seismic data acquired in the original profile.

Data obtained from each seismic sounding was entered into a computer database and evaluated with a program entitled "GeoLogic REFRACT, version 3". This program provides interactive interpretation of first arrival refracted seismic waveforms as identified by the seismograph and recorded in the field. Seismic data and results were also field evaluated and compared with existing geologic information (e.g. soil boring logs and direct push data).

Soil boring and direct push boring data were also available within the study area and were used as a comparison to the results of the seismic survey. Soil boring data consisted of one boring completed at the intersection of the two seismic lines. Direct push data (inferred bedrock depth due to penetration refusal) was available at 20 locations within the central portion of the site, as shown in Figure 2. The depth to bedrock was also inferred from the available direct push data where the boring encountered refusal. Those penetration refusal depths were used for 20 locations within the central portion of the site, as shown in Figure 2. Penetration refusal depths for the remaining 43 direct-push borings (located along the S-N and W-E seismic transects) were used for geologic and depth to bedrock information and compared to seismic sounding data during the field investigation. The comparison of data provided a control measure regarding confirmation of the depth to bedrock as determined from the seismic soundings. Lithologic or density characteristics of underlying strata and their associated velocities were also identified.

4.0 SEISMIC REFRACTION SURVEY ANALYSIS AND RESULTS

Results of the seismic sounding survey provided depth to bedrock data and information on stratigraphic characteristics of the overlying unconsolidated soils within the study area. Seismic data interpretation indicates a bedrock surface with varied vertical relief consisting of low-lying buried channels along both the south-north and west-east cross-sections, as shown in Figure 3. Unconsolidated soils overlying the bedrock were characterized based on seismic velocity and soil boring data.

A summary of seismic data obtained in the survey, including velocities of each identified layer and bedrock elevation data, are provided in Tables 1 and 2. Table 1 summarizes seismic data from the south-north seismic line. Table 2 summarizes data from the west-east seismic line and outlying soundings. Copies of the plotted seismic data (sounding models) used for determining velocities and depth to bedrock are provided in Appendix A.

South-North Seismic Line:

Eight of the 22 seismic sounding models in the south-north seismic line indicated a three-layer stratigraphic sequence. Twelve soundings exhibited a two-layer stratigraphic sequence. Soundings with three layers tended to be at locations within the valley area associated with an unnamed creek, whereas soundings with two layers were most often located in more upland areas. The velocity variations between layers were in response to the differences in density and lithologic characteristics of each layer.

An evaluation of the data in Table 1 indicates the velocities (V_1) of the first layer ranged from 1002 to 1978 feet per second (fps). Generally, the first layer velocity of 1324 fps suggests loosely compacted soils. This velocity correlates well with the boring log for Monitoring Well 941148 (at SS8), which describes silts and sandy clays overlying a sand and gravel layer and is shown in Appendix B. The indicated range in velocities within the first layer are attributed to the varied composition of silt, clay and sandy clay.

The second layer, at soundings with a three-layer sequence, is associated with more dense deposits. These deposits, based on available soil boring data, are inferred to consist of coarse sands or gravels. Residual weathered bedrock material is also suspected to contribute to the higher velocities of this layer at some locations. Velocities (V_2) of the second layer, at three-layer soundings, were found to range from 1460 fps to 3259 fps. The range in values suggests a significant variation of the second layer's density along the seismic line, indicating layers may vary from alluvial materials to highly weathered shale bedrock overlying the more consolidated bedrock surface.

The third layer, at soundings with a three-layer sequence and the second layer at soundings with a two-layer sequence, is identified as shale bedrock of the Pierre Formation. Velocities associated with this formation ranged from 4590 fps to 8314 fps, with an average velocity of 6185 fps. The variation of velocity reflects a varied density of the bedrock surface. This density variation correlates with regional data that describes the competency of the Pierre Shale as variable. It is suspected that a more dense shale bedrock surface was encountered at soundings with higher velocities and relatively

lower velocities at soundings where a less dense (slightly weathered) shale was encountered. A geologic cross-section illustrating stratigraphic conditions along the south-north seismic line is provided in Figure 3. The bedrock is shown with a variable surface comprised of peaks and channels with a vertical relief of approximately 10 to 15 feet. The thickness of the overlying soils varies from five to 29 feet, with thicker soil deposits occurring within the channels and relatively thin soil layers overlying bedrock highs. Overlying soils in the areas to the north and south of the creek valley tend to be at a more consistent thickness of approximately 20 to 25 feet.

The cross-section also shows average seismic velocities for the varied soil types and the shale bedrock. The averages are based on velocity trends observed at each seismic sounding. First layer soil velocities tend to be less than 1500 fps, which suggests that the surficial soils are similar to the silts and sandy clays identified at the boring for Monitoring Well 941148 and at the adjacent sounding SS8.The higher velocity soils are suspected of having a higher sandy clay content.

At locations where a three-layer sequence was identified, the second layer soils appear to be more dense with average velocities of between 1719 and 3157 fps. These layers are inferred to be comprised of sands and gravels associated with alluvium and/or highly weathered shale bedrock. These higher velocity soils are also located near the unnamed creek valley where the existence of coarser alluvial material could be expected.

Seismic data along the south-north seismic line was also compared with soil and direct push depth data from the locations shown in Figure 2. Depth to bedrock information obtained from soil boring and direct push data are indicated in Figure 2 and summarized in Appendix B.

Depth to bedrock information as determined from direct push data is also shown in Figure 3. The bedrock surface is less detailed than that determined by seismic data; however, the general trend of lows and highs of the bedrock surface was found to correlate well with the seismic results. In addition, higher TCE concentrations from the direct push data (Figure 2) were found to occur in bedrock lows (channels). This condition is most evident in the central portion of the cross-section where relatively high TCE concentrations occur within saturated bedrock channels between seismic soundings SS8 and SS14. Direct push data at locations with relatively high bedrock surfaces did not encounter ground water, inferring the bedrock highs isolate saturated zones and the contaminants found within the ground water. Significant bedrock highs which appear to have this effect are at soundings SS10, SS15, and SS19. Lower level TCE concentrations are also found within the bedrock lows between SS4 and SS6.

<u>West-East Seismic Line:</u>

Seismic velocities along the west-east seismic line varied somewhat from the conditions identified along the south-north seismic line; however, the overall stratigraphic conditions are similar. Three of the nine seismic sounding models along the west-east line indicated a three-layer sequence and a two-layer sequence was identified at the remaining six soundings.

An evaluation of the data in Table 2 indicates velocities (V_1) of the first layer ranged from 1457 to 2234 fps, with an average velocity of 1883 fps. The slightly higher average velocity of the first layer along this line infer the surficial soils are more dense than soils along the south-north seismic line. It is uncertain if the velocity changes are a result of more compacted soils and/or a change in soil type.

The second layer at soundings with a three-layer sequence is associated with more dense deposits. These deposits were again inferred to consist of coarse sands, gravels, and/or highly weathered shale bedrock. Velocities (V_2) of the second layer, at three-layer soundings, were found to range from 2109 to 3859 fps. In comparison to the south-north seismic line, the second layer soil type appears to be more consistent.

Velocities of the underlying shale bedrock, at all nine soundings, ranged from 4422 to 8312 fps. The varied competency of the bedrock is again indicated. Dense shale is associated with higher velocities and more weathered shale with lower velocities.

The geologic cross-section shown in Figure 3, reflects the regional southeasterly slope of the bedrock surface. The bedrock surface is comprised of peaks and channels with a vertical variation of approximately 10 feet. Soils that overlie the bedrock vary from seven to 27 feet in thickness. At sounding SS28, a notably deeper bedrock channel is indicated. The location of this channel correlates with the topographic low of the unnamed creek valley centerline.

As in the south-north cross-section, average seismic velocity trends of subsurface materials are indicated. The average velocities of most surficial soils were less than 1775 fps. The average velocity of the layer in contact with the bedrock surface was relatively higher at 2540 fps. These soils are suspected to be similar to the higher velocity soils in contact with the bedrock within the central portion of the south-north cross-section (i.e. sands and\or highly weathered shale).

The general trend of the bedrock surface, as determined by direct push data, is also shown in Figure 3. The surface shown is less detailed than that determined by seismic data; however, the overall trend of the bedrock surface correlates well. Water quality information from the direct push data, also indicated the effects of the variable bedrock surface. As in the south-north cross-section, high TCE concentrations have been identified in ground water within bedrock lows. The bedrock high between soundings SS26 and SS27 also appears to separate contaminated ground water in the west portion of the cross-section from the deeper channel identified At sounding SS28.

<u>Bedrock Contour Map/Surface Plot</u>:

Results of the seismic data evaluation along both seismic lines was found to correlate with depth to bedrock data obtained from the previous direct push investigation. Using both sets of data, as well as the outlying seismic sounding data, a site-wide contour map of the bedrock surface was developed. The contour map and a corresponding bedrock surface plot describing the configuration of the bedrock surface for the entire study area are provided in Figure 4. (Note that the depth to bedrock data is concentrated primarily along the south-north and west-east transects, resulting in broader interpolation of the bedrock data within the southeastern and northeastern portion of the site.)

The bedrock surface illustrated in Figure 4 is a reflection of the surface topography also shown on Figure 4. Most notable are the bedrock highs in the southwestern and northeastern portions of the site and the general southeastern slope of the bedrock. The seismic and direct push data, however, does provide additional detail of features within the identified bedrock surface trend.

The contour map provides a plan view of the bedrock surface, where bedrock channels identified in the cross-sections appear to extend across the site. Past erosional processes have likely incised the shale forming a sinuous channel network that descends in a south-easterly direction. Bedrock channels divert around relative small bedrock highs centered at coordinates 133,300N/1,164,000E; 134,300N/1,164,000E; 134,000N/1,164,300E; 135,600N/1,164100E; and 134,100N/1,164,700E.

These bedrock channels appear to affect shallow ground water and contaminant flow direction. The channel network appears to correlate well with relatively high TCE concentrations identified at direct push and existing well locations shown in Figure 2. Examples include TCE concentrations of up to 226.7 ppb (near SS11) and 356.8 ppb (at water well WWEXS380). The two data point locations are approximately 1500 feet apart in a southeast-northwest direction, yet lower concentrations are found at other interim data point locations. It is suspected that TCE contamination concentrates within the meandering channels, resulting in the apparent scattering of water quality impacts.

An illustration of all suspected preferred ground water flow paths, as determined from the seismic investigation, is presented in the bedrock surface plot in Figure 4. This plot provides a three-dimensional view of the bedrock surface with reference to surface features such as the housing area within the southwestern portion of the site and wells. Again, the general southeasterly ground water flow direction is indicated; however, the localized effects the bedrock channels on flow is also inferred. These preferred flow paths (within bedrock channels) are suspected to have the highest TCE concentrations which are reported to originate from the area west of the site.

5.0 SUMMARY AND CONCLUSIONS

Based on the results of seismic refraction survey, the depth to bedrock and the configuration of the bedrock surface along both the south-north and west-east seismic lines were identified. Seismic data and existing depth to bedrock information (i.e. soil and direct push borings) were also used in the development of a site-wide evaluation of the configuration of the bedrock surface. Lithologic characteristics of the soils overlying the bedrock surface were also identified. The following text summarizes the geologic characteristics of the site, as determined from this investigation:

- The investigation has identified a bedrock surface configuration that is comprised of higher elevations within the southwestern and northern portions of the study area. The configuration of the bedrock surface also appears to generally reflect the topographic relief at the site, where the lower surface elevations are defined by the southeasterly flowing unnamed creek.

- The bedrock is comprised of shales associated with the Pierre Formation. Lower elevations of the bedrock surface trend downward in a southeasterly direction through the central portion of the site. The bedrock within this area also appears to consist of meandering channels incised into the shale. Vertical variation between the channels and bedrock highs, generally ranged from 10 to 15 feet.

- The soils overlying the bedrock were identified as consisting of silts, clays and sandy clays; however, a second underlying layer sand and/or gravel content is inferred to occur primarily within the low areas defined by the creek. This second soil layer may also contain highly weathered shales (residual soil) derived from the bedrock. The total thickness of the soils overlying bedrock were found to range from five to 28 feet.

- Based on available water quality data (from direct push borings), the spatial distribution of TCE contamination across the site appears to be influenced by the location of buried bedrock channels. Seismic data indicate that these channels may contain relatively permeable soils which, as illustrated in Figure 4, appear to provide preferred ground water flow paths and potential routes for contaminant (TCE) migration across the site.

6.0 RECOMMENDATIONS

The seismic refraction survey, direct push, and water quality data indicate that the bedrock surface is variable with meandering channels incised into the Pierre Shale. The preferred ground water flow paths and contaminant (TCE) migration appears to follow the existing shale channels in a southeasterly direction. Previous investigations have included soil borings and ground water data from one monitoring well (SB9411120 converted to MW941148). Ten additional soil borings and monitoring wells are recommended to characterize the lithology within the bedrock channels as well as determine the magnitude and extent of TCE contamination within the study area. The locations of these proposed monitoring wells are shown on Figure 4.

Correspondence from the USEPA (11-30-95) states that "ground water wells will need to be installed in both high contamination areas and in low contamination areas.... Also, the samples from locations in the eastern portion of the investigation contained relatively high levels of TCE. Future investigations in the areas of these sample points would be necessary to determine the extent of the identified contamination." The letter further states that "the immediate concern is to accurately identify the outer limits of the TCE contamination (above the MCL of 5 $\mu g/L$) which would require remediations," see Appendix C for a copy of the letter.

The magnitude and extent of TCE contamination has exceeded previous expectations. Seven of the proposed soil borings/monitoring wells are located in existing bedrock channels within the study area, but three additional soil borings/monitoring wells are proposed southeast of the study area. These three additional wells will be installed downgradient of the known extent of TCE contamination (356.8 $\mu g/L$ TCE in WWEXS380) in an attempt to identify the outer limits of the contamination.

TABLE 1
SOUTH - NORTH SEISMIC LINE SUMMARY
BG04/TCE INVESTIGATION
ELLSWORTH AFB, SOUTH DAKOTA
(Page 1 of 2)

Seismic Sounding No.	Surface Elevation (ft-NGVD)[1]	Velocity of Layers[2]			Depth to Bottom of Layer (North to South)		Depth to Bedrock	Bedrock Surface Elevation
		V_1 (fps)	V_2 (fps)	V_3 (fps)	D_1 (ft)	D_2 (ft)	Range (ft) (North to South)	Range (ft -NGVD) (North to South)
SS1	3212	1152	5561	-	17.5 - 18.5	-	17.5 - 18.5	3194 - 3193
SS2	3220	1063	4964	-	19 - 18	-	19 - 18	3199 - 3200
SS3	3226	1002	7289	-	22 - 20	-	22 - 20	3204 - 3206
SS4	3227	1287	7211	-	24 - 29	-	24 - 29	3203 - 3198
SS5	3224	1545	4143	-	28 - 27	-	28 - 27	3196 - 3197
SS6	3220	1373	6818	-	22 - 18.5	-	22 - 18.5	3198 - 3201
SS7	3214	1505	5933	-	15 - 16	-	15 - 16	3199 - 3198
SS8	3212	1101	1460	4590	5 - 6	18 - 18	18 - 18	3194 - 3194
SS9	3209	1351	2581	4706	7 - 7	23 - 23	23 - 23	3186 - 3186
SS10	3205	1058	5858	-	15 - 14	-	15 - 14	3190 - 3191
SS11	3201	1109	1719	6502	9 - 1	24 - 23	24 - 23	3177 - 3176
SS12	3200	1095	3157	5632	13 - 4	18 - 28	18 - 28	3182 - 3172
SS13	3198	1329	5632	-	12 -14	-	12 - 14	3186 - 3184
SS14	3197	1872	7501	-	17 - 19	-	17 - 19	3180 - 3178
SS15	3196	1297	7596	-	6 - 11	-	6 - 11	3190 - 3185

TABLE 1
SOUTH - NORTH SEISMIC LINE SUMMARY
BG04/TCE INVESTIGATION
ELLSWORTH AFB, SOUTH DAKOTA
(Page 2 of 2)

Seismic Sounding No.	Surface Elevation (ft-NGVD)[1]	Velocity of Layers[2]			Depth to Bottom of Layer (North to South)		Depth to Bedrock	Bedrock Surface Elevation
		V_1 (fps)	V_2 (fps)	V_3 (fps)	D_1 (ft)	D_2 (ft)	Range (ft) (North to South)	Range (ft -NGVD) (North to South)
SS16	3200	1280	3259	8132	8 - 2	22 - 21	22 - 21	3178 - 3179
SS17	3202	1483	2122	7163	6 - 0	19 - 24	19 - 24	3183 - 3178
SS18	3205	1978	8314	-	22 - 24	-	22 - 24	3183 - 3181
SS19	3208	1484	4639	-	15 - 13	-	15 - 13	3193 - 3191
SS20	3210	1535	2171	6533	6 - 5	30 - 27	30 - 27	3180 - 3177
SS33	3213	1008	1777	5234	7 - 5	23 - 25	23 - 25	3190 - 3188
SS34	3216	1231	6134	-	23 - 22	-	23 - 22	3193 - 3194

[1]NGVD = National Geodetic Vertical Datum. (Surface elevations from surveyed coordinates rounded to the nearest foot).
[2]Indicates velocities are averaged values from both forward and reverse profiles (fps - feet per second).

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TABLE 2
WEST - EAST SEISMIC LINE SUMMARY
BG04/TCE INVESTIGATION
ELLSWORTH AFB, SOUTH DAKOTA
(Page 1 of 2)

Seismic Sounding No.	Surface Elevation (ft-NGVD)[1]	Velocity of Layers[2]			Depth to Bottom of Layer (West to East)		Depth to Bedrock	Bedrock Surface Elevation
		V_1 (fps)	V_2 (fps)	V_3 (fps)	D_1 (ft)	D_2 (ft)	Range (ft) (West to East)	Range (ft -NGVD)[1] (West to East)
SS21[3]	3213							
SS22	3208	2234	4422	-	27 - 17	-	27 - 17	3181 - 3191
SS23	3202	1488	3448	4584	13 - 14	22 - 24	22 - 24	3180 - 3178
SS24	3197	1457	3859	6190	15 - 8	26 - 16	26 - 16	3171 - 3181
SS25	3192	1797	2109	7738	7 - 1	24 - 22	24 - 22	3168 - 3170
SS26	3189	2149	4824	-	14 - 14	-	14 - 14	3175 - 3175
SS27	3188	2234	4422	-	27 - 17	-	27 - 17	3161 - 3171
SS28	3186	2037	8312	-	16 - 23	-	16 - 23	3170 - 3163
SS29	3189	1783	4401	-	13 - 7	-	13 - 7	3178 - 3182
SS30	3189	1766	4243	-	12 - 16	-	12 - 16	3177- 3173
OUTLYING SOUNDINGS								
SS31	3193	1178	5130	-	8 - 10	-	8 - 10	3185 - 3183
SS32	3186	1727	4422	-	10 - 10	-	10 - 10	3176 - 3176
SS35	3205	1402	6440	-	17 - 14	-	17 - 14	3188 - 3191
SS36	3224	1685	5134	-	31 - 34	-	31 - 34	3193 - 3190

TABLE 2
WEST - EAST SEISMIC LINE SUMMARY
BG04/TCE INVESTIGATION
ELLSWORTH AFB, SOUTH DAKOTA
(Page 2 of 2)

Seismic Sounding No.	Surface Elevation (ft-NGVD)[1]	Velocity of Layers[2]			Depth to Bottom of Layer (West to East)		Depth to Bedrock	Bedrock Surface Elevation
		V_1 (fps)	V_2 (fps)	V_3 (fps)	D_1 (ft)	D_2 (ft)	Range (ft) (West to East)	Range (ft -NGVD)[1] (West to East)
SS37	3214	1064	5510	-	16 - 20	-	16 - 20	3198 - 3194
SS38	3216	1412	4850	-	22 - 22	-	22 - 22	3194 - 3194

[1]NGVD = National Geodetic Vertical Datum. (Surface elevations from surveyed coordinates rounded to the nearest foot).
[2]Velocities are averaged values from both forward and reverse profiles (fps - feet per second).
[3]Seismic sounding SS21 omitted due to identified inversion layer.

W:\55203\REPORTS\ELLSSEIS.SDP

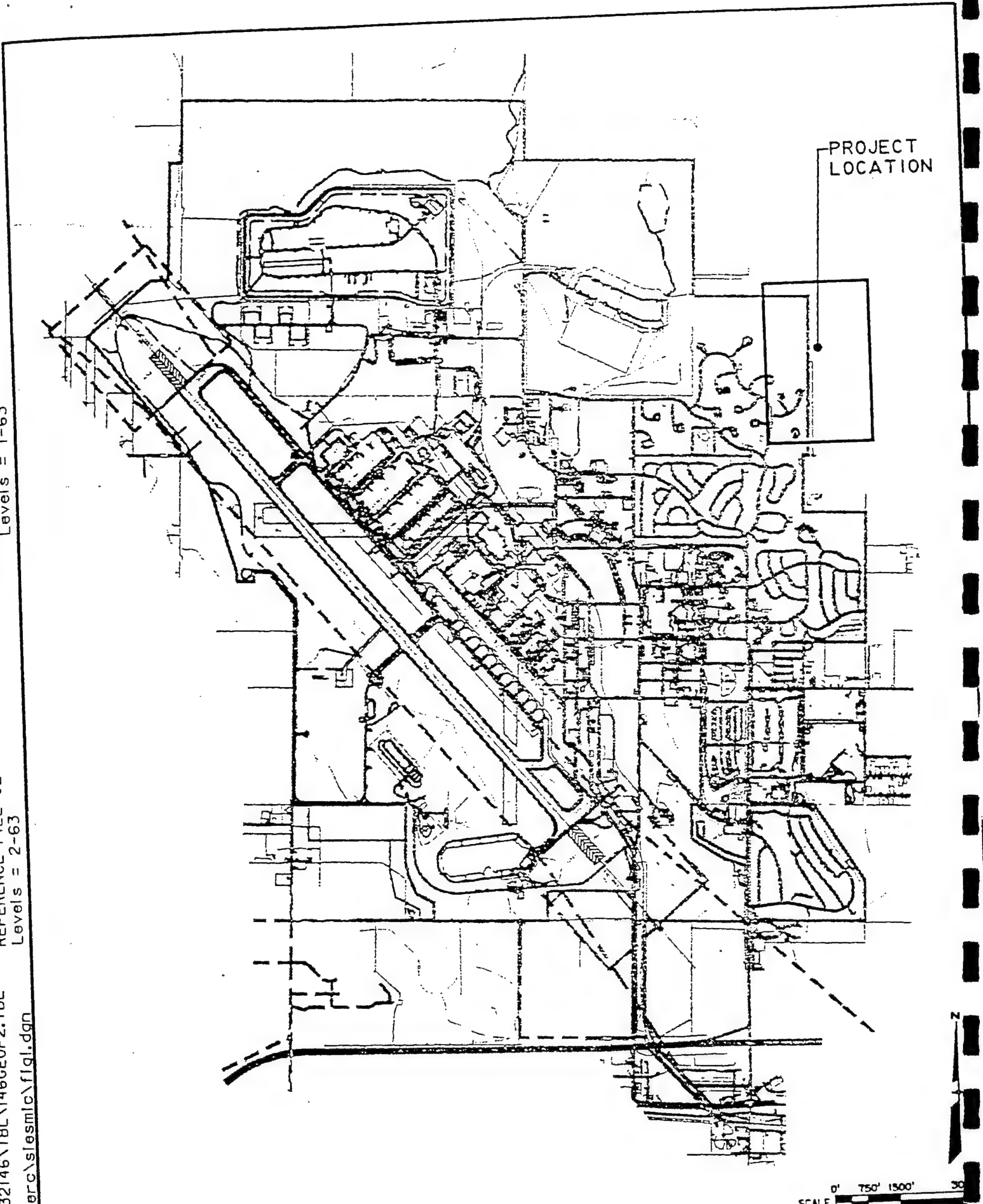

FIGURE 1
GENERAL LOCATION MAP

SEISMIC REFRACTION SURVEY
BG04/TCE INVESTIGATION
ELLSWORTH AIRFORCE BASE, SOUTH DAKOTA

DATE=Thu Jan 11 07:00:28 1996
PEN TABLE= F:\132146\TBL\146GEOP2.TBL
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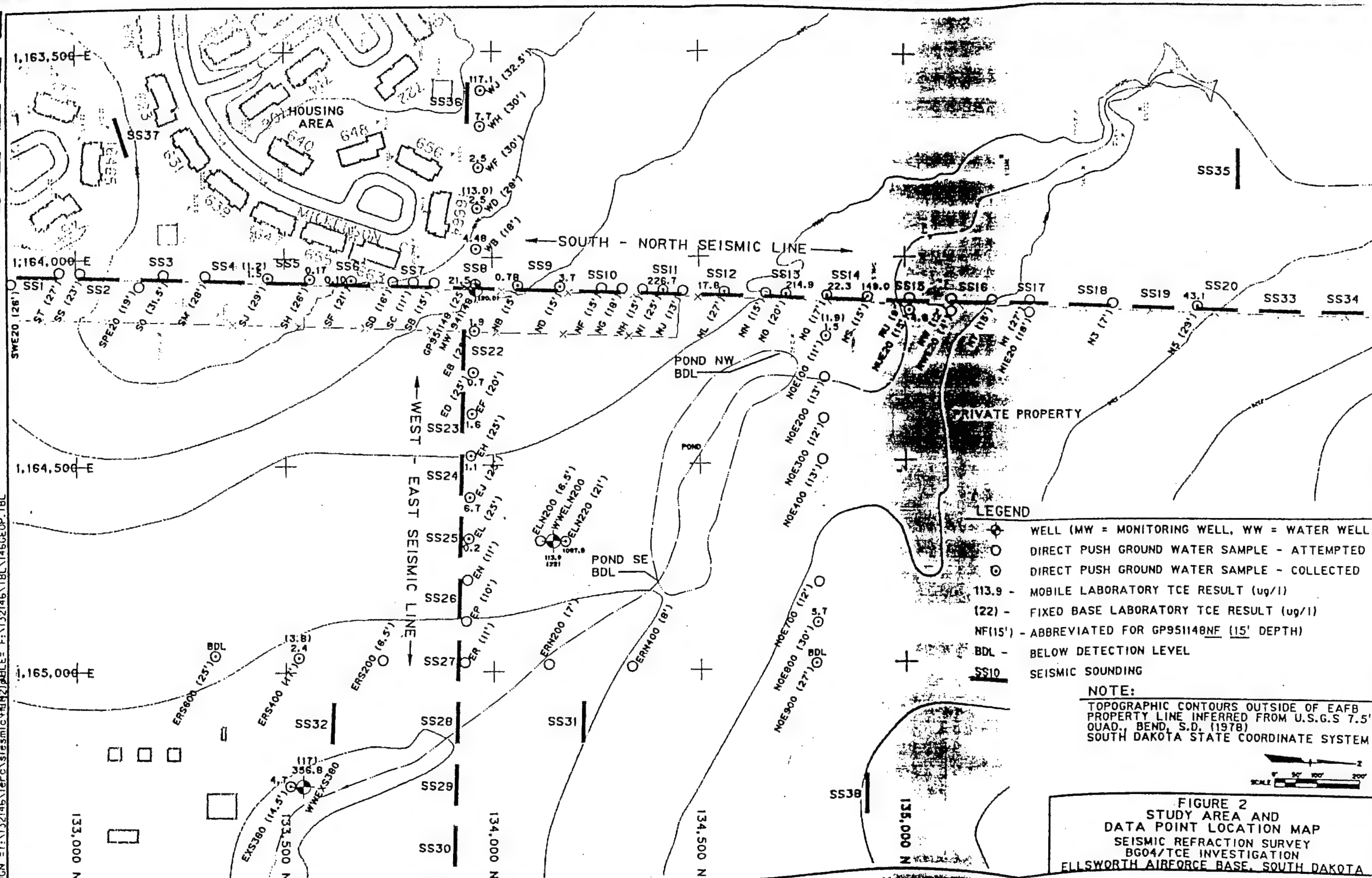
REFERENCE FILE 02 = f:\132146\lerc\base\base400\CA6_40
Levels = 2-63



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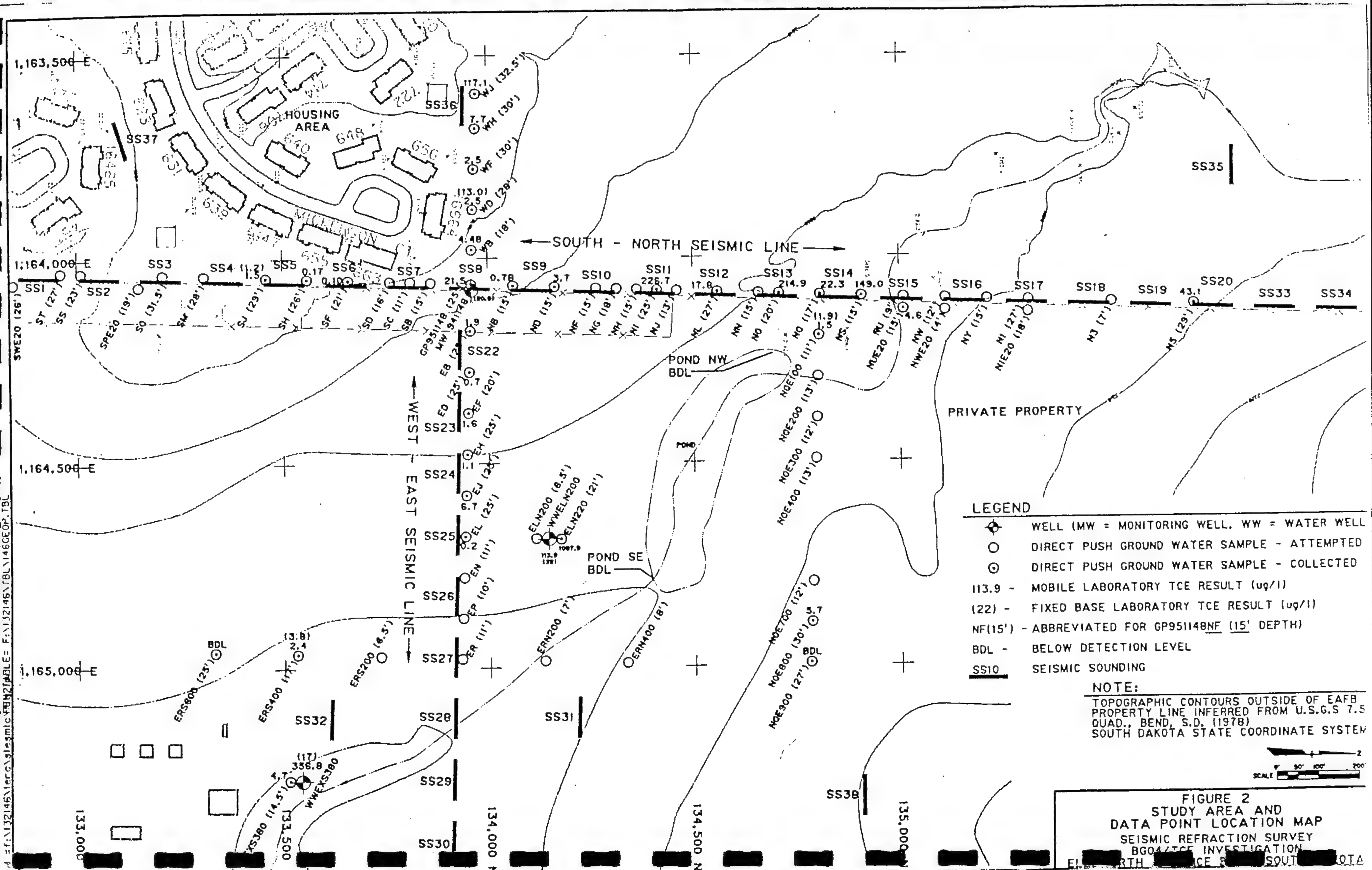

FIGURE 2
STUDY AREA AND
DATA POINT LOCATION MAP
SEISMIC REFRACTION SURVEY
BG04/TCE INVESTIGATION

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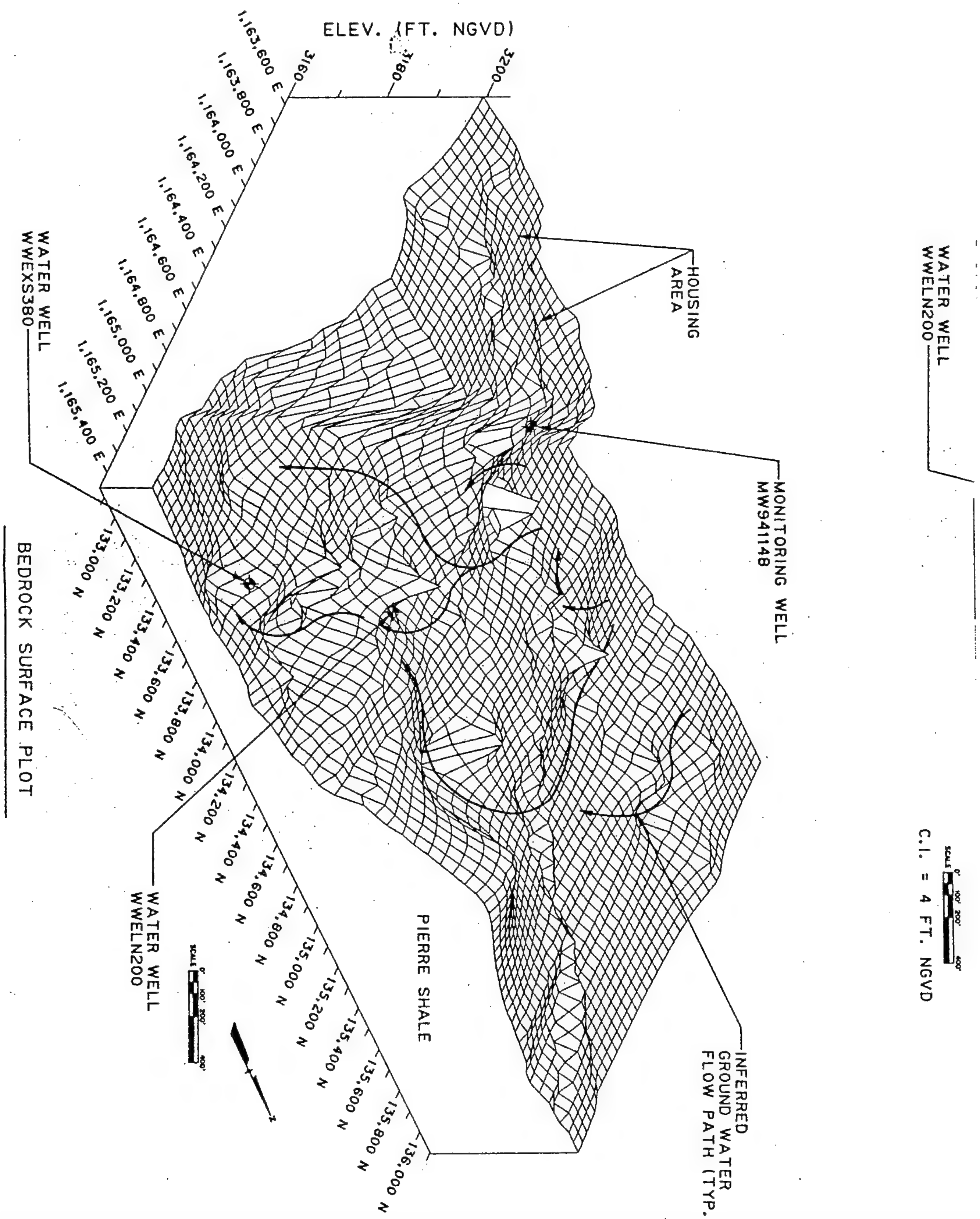
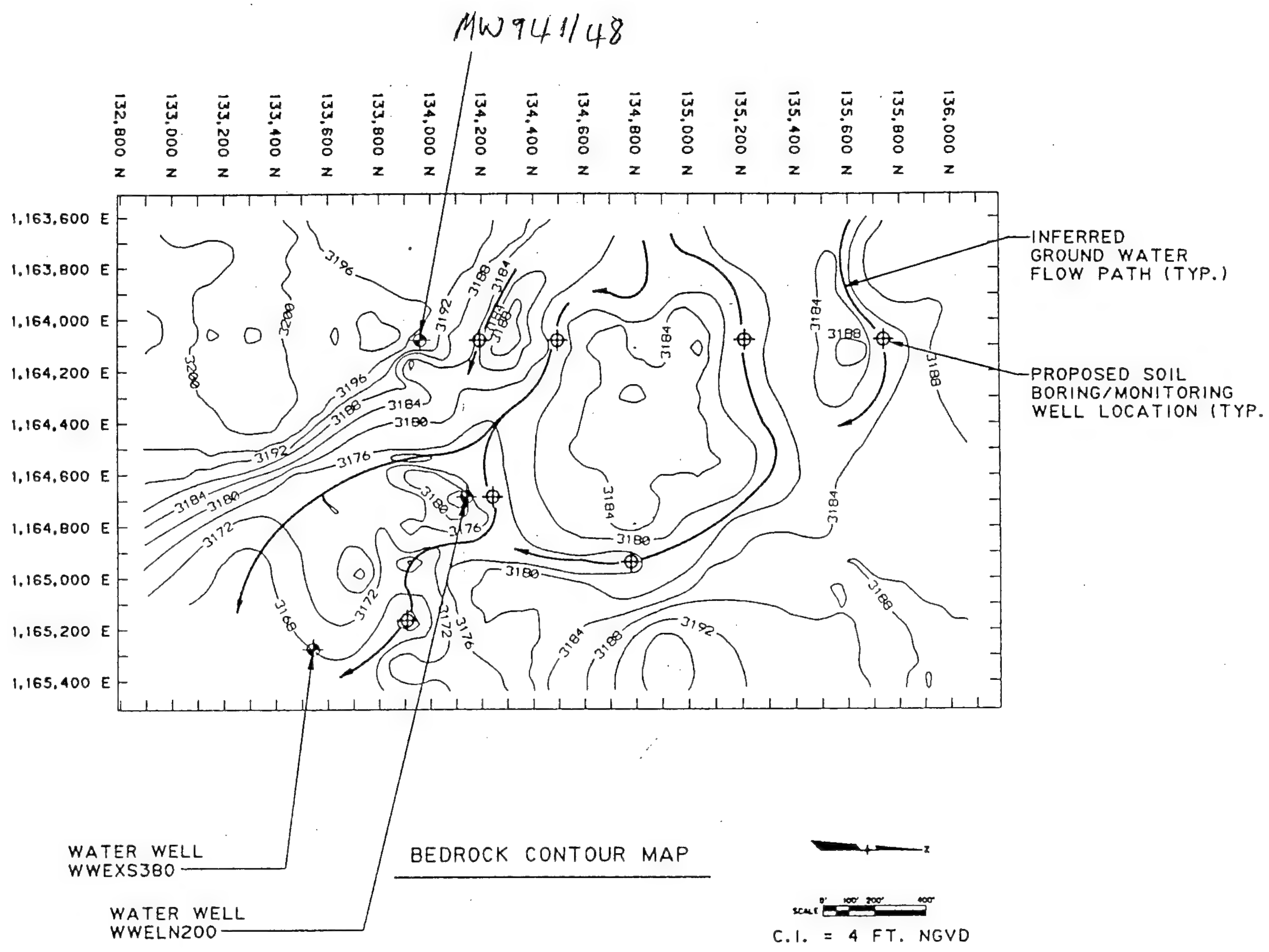
DATE=Tue Jan 23 12:03:13 1996
DGN =f:\132146\terc\siesmic\fig4.plt

REFERENCE FILE 02 = F:\132146\TERC\SIESMIC\SURF2.plt
Levels = 1-63
REFERENCE FILE 03 = F:\132146\TERC\SIESMIC\22X34.BOR
Levels = 1-63
REFERENCE FILE 05 = f:\132146\terc\base\base400\col_40
Levels = 1-63
REFERENCE FILE 06 = f:\132146\terc\base\base400\co5_40
Levels = 1-63

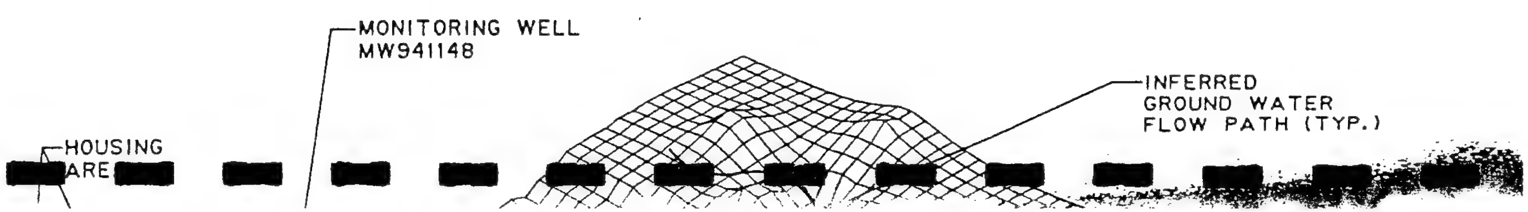


BEDROCK SURFACE PLOT



BEDROCK CONTOUR MAP

C.I. = 4 FT. NGVD



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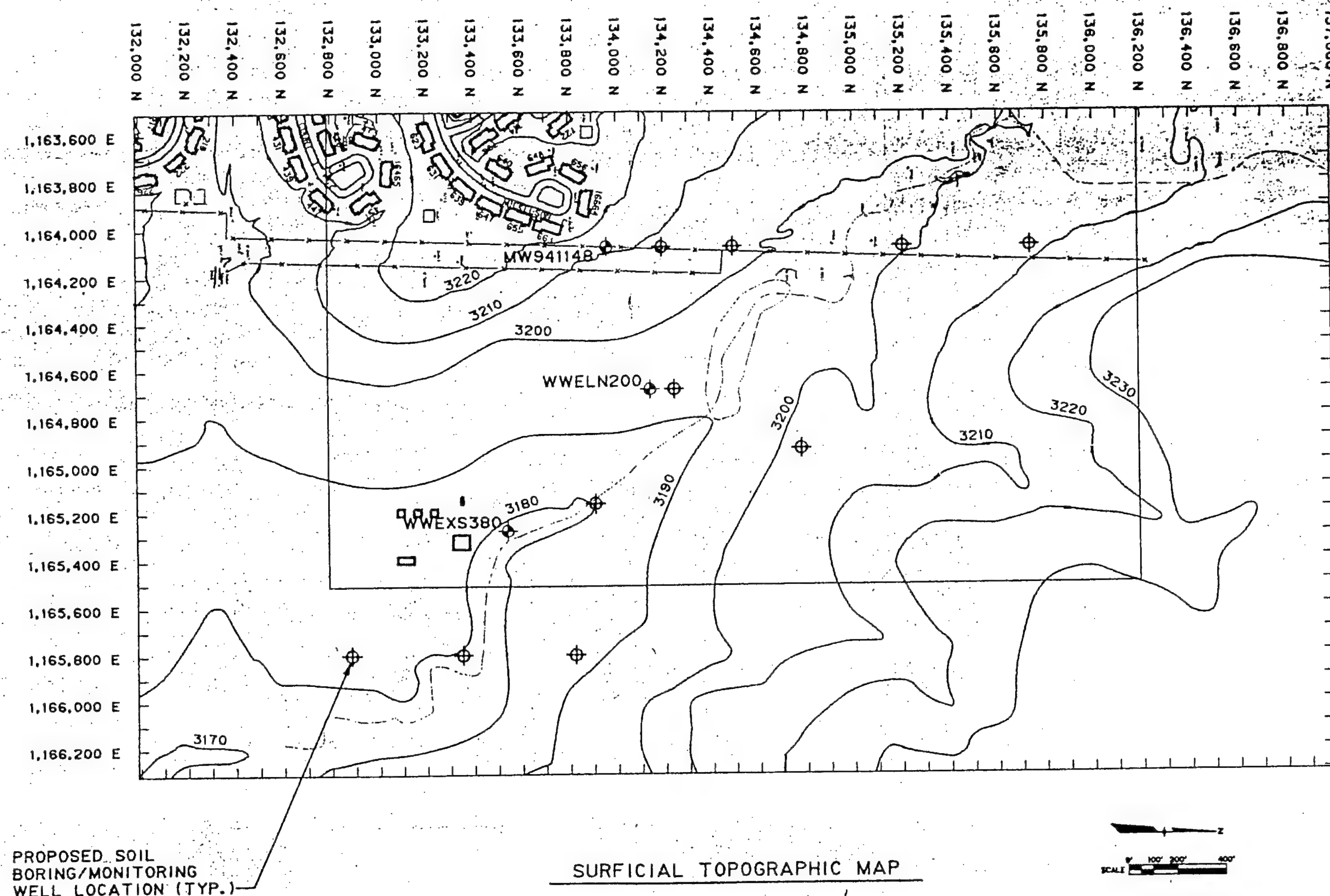
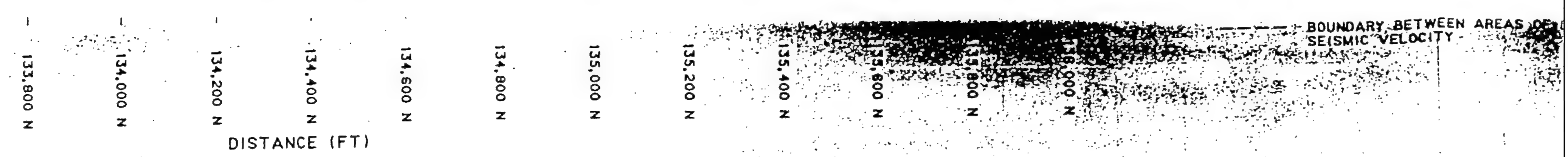
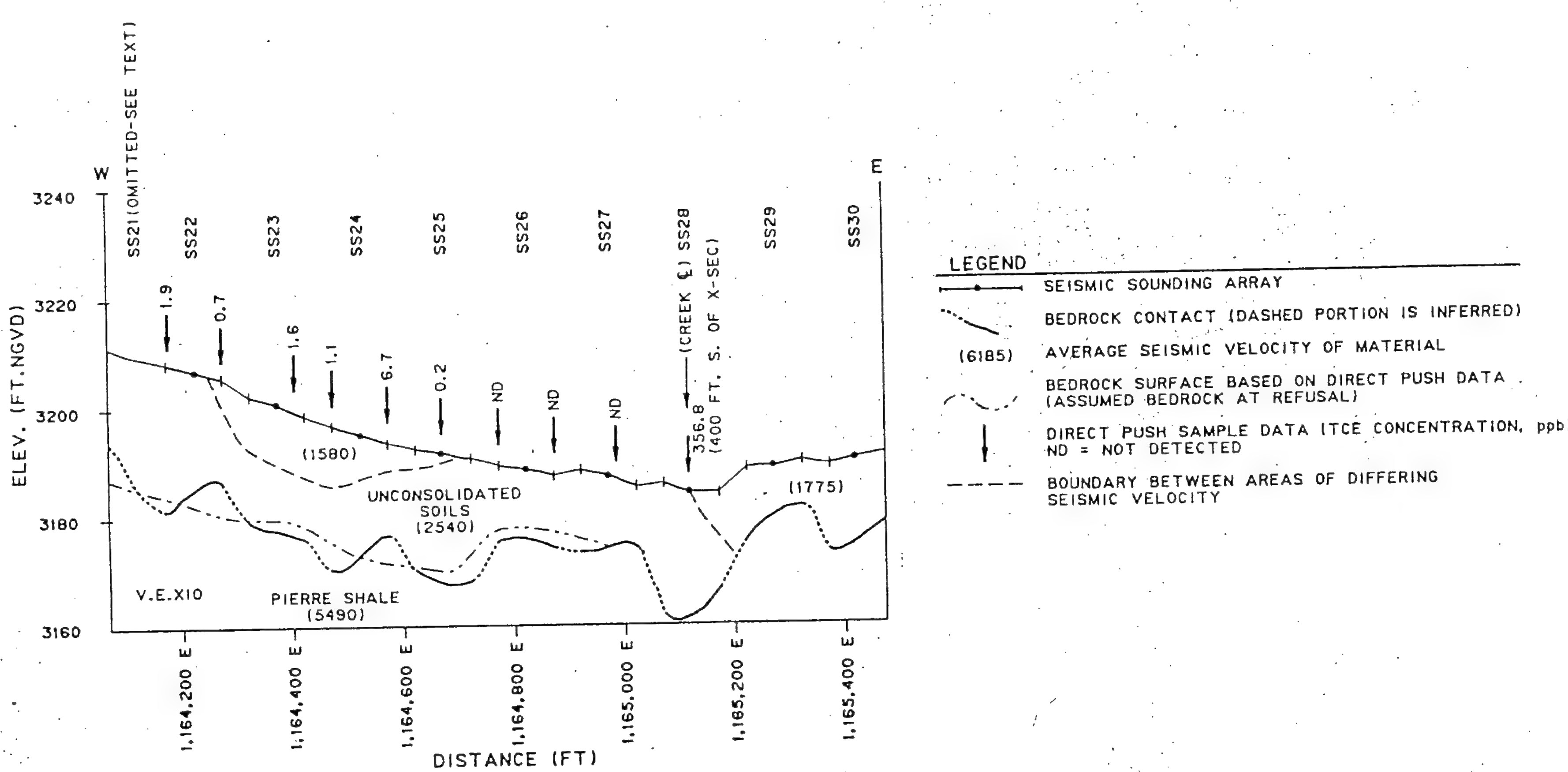


SURFICIAL TOPOGRAPHIC MAP

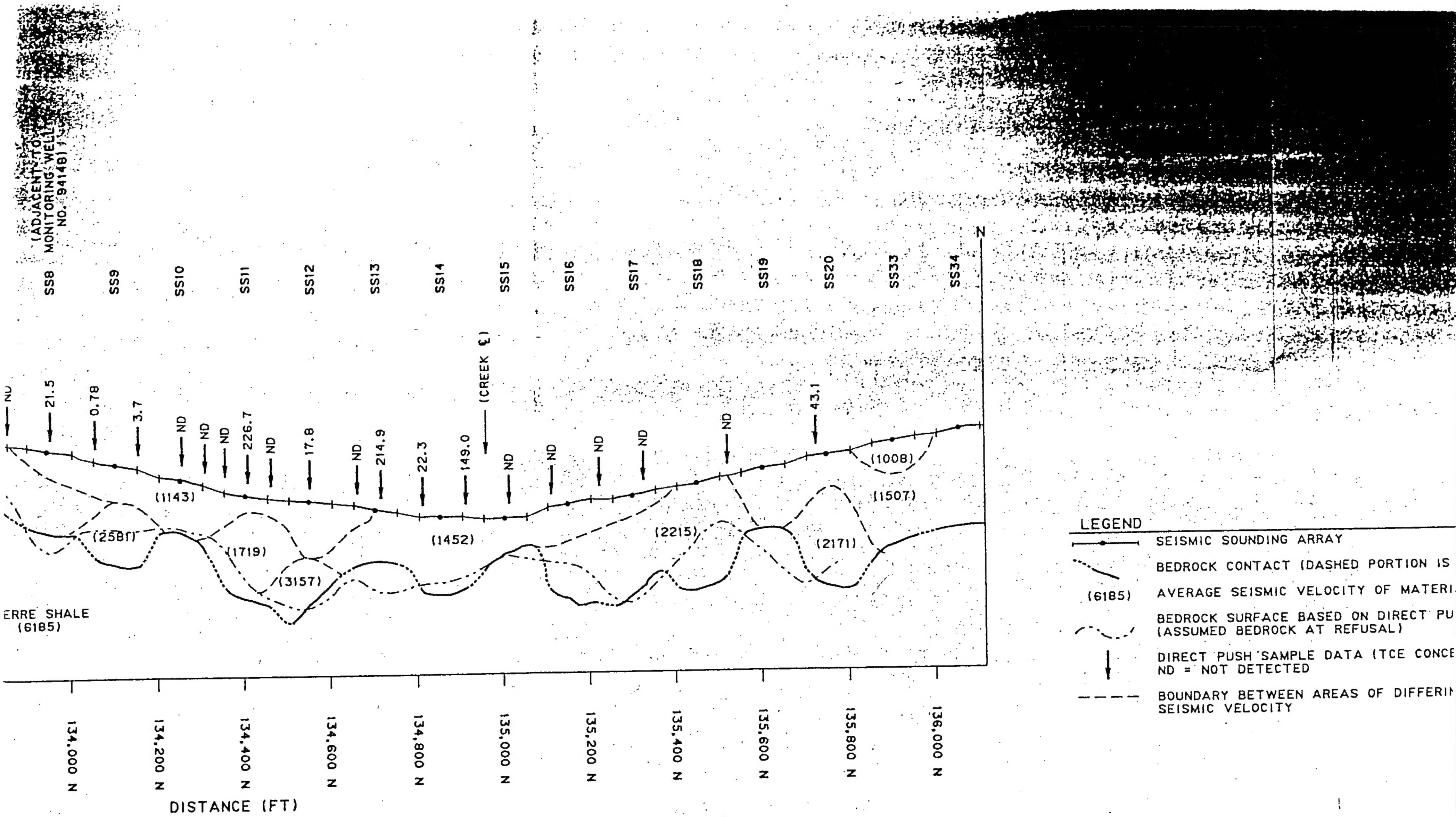
NOTE:
TOPOGRAPHIC CONTOURS OUTSIDE OF EAFB
PROPERTY LINE INFERRED FROM U.S.G.S 7.5'
QUAD., BEND, S.D. (1978)
SOUTH DAKOTA STATE COORDINATE SYSTEM



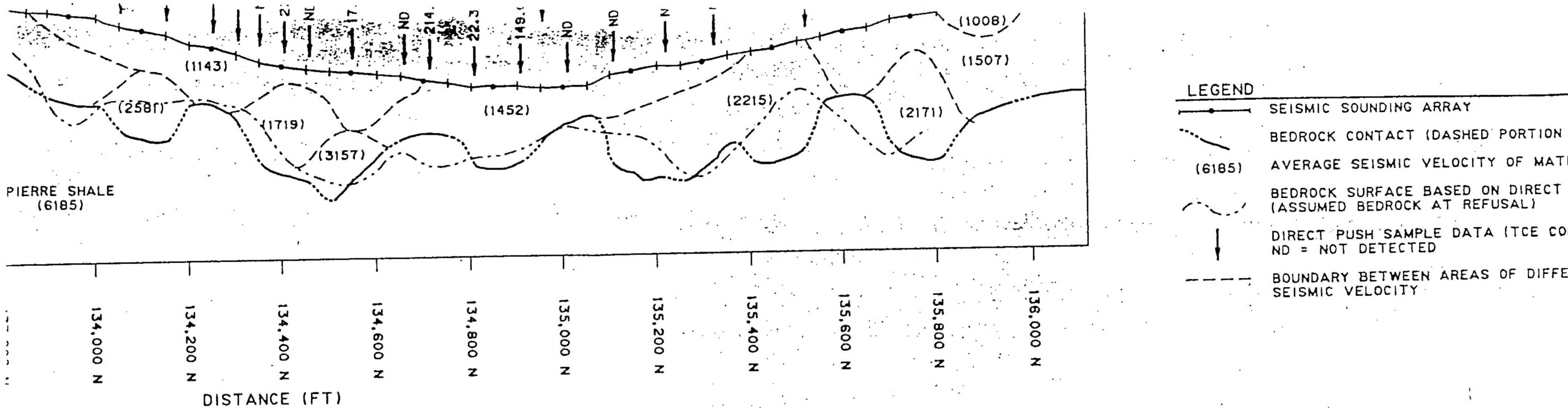
SOUTH-NORTH GEOLOGIC CROSS-SECTION



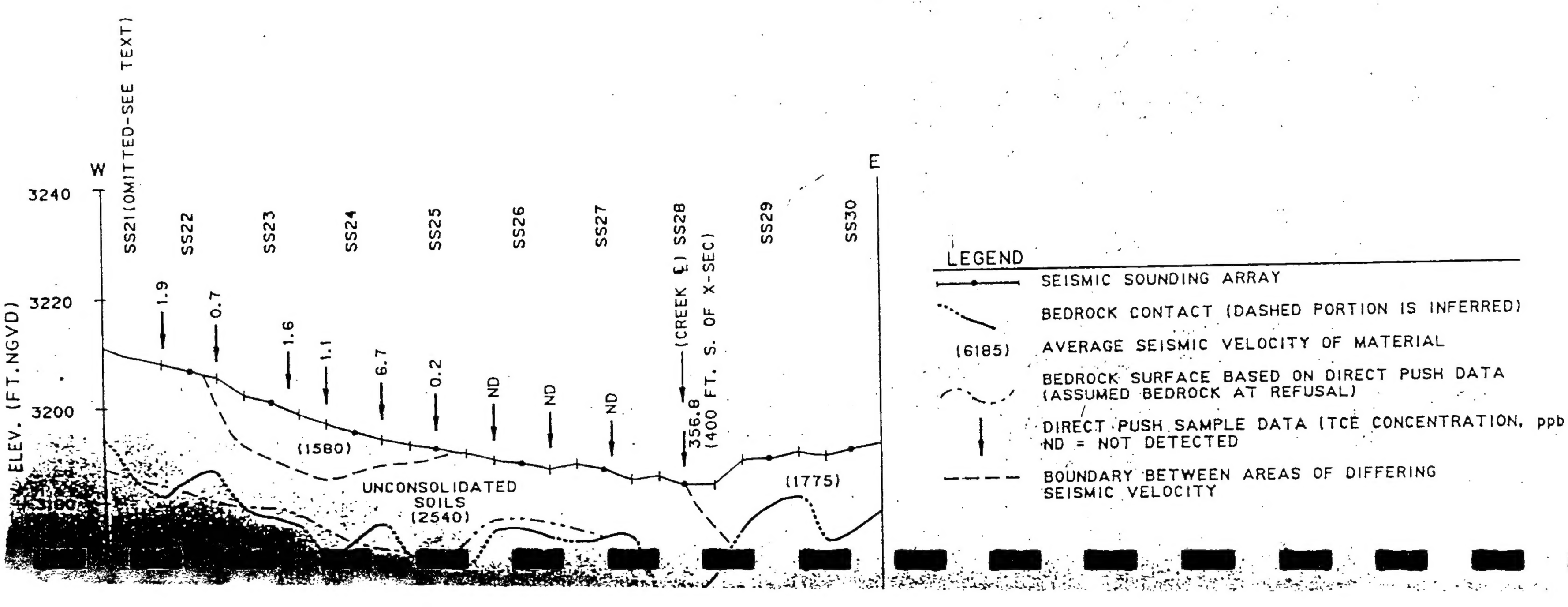
WEST-EAST GEOLOGIC CROSS-SECTION

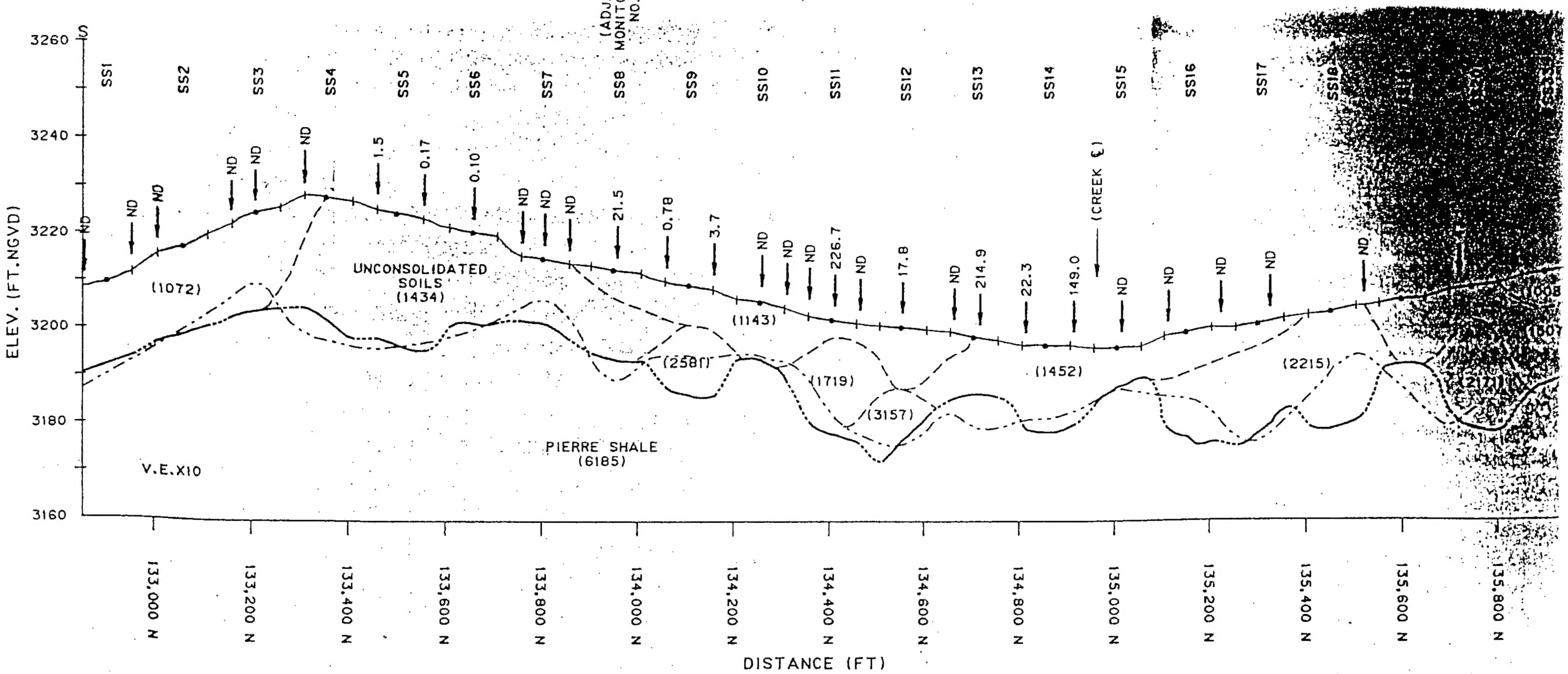


SOUTH-NORTH GEOLOGIC CROSS-SECTION



SOUTH-NORTH GEOLOGIC CROSS-SECTION





SOUTH-NORTH GEOLOGIC CROSS-SECTION

ITTED-SEE TEXT)

DIRECT PUSH DEPTH TO BEDROCK SUMMARY[1]

DP Point	Approx. Surface Elev. (Ft-NGVD)	Depth Bedrock (ft)	Bedrock Elev/ (ft-NGVD)
1	3198	11	3187
2	3196	13	3183
3	3198	12	3186
4	3198	13	3185
5	3201	12	3189
6	3202	30	3172
7	3203	27	3176
8	3191	8	3183
9	3188	7	3181
10	3188	6.5	3181.5
11	3189	17	3172
12	3191	25	3166
13	3179	14.5	3164.5
14	3195	21	3174
15	3195	6.5	3188.5
16	3218	18	3200
17	3221	28	3193
18	3223	30	3193
19	3224	30	3194
20	3228	32.5	3196.5

[1] DP Data from locations other than along seismic lines.

Note: Depth to Bedrock assumed At refusal.